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SOCIO-ECONOMIC IMPACT ANALYSIS OF LEAD PHASE-DOWN
CONTROL OPTIONS, 1984.

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SOCIO-ECONOMIC IMPACT ANALYSIS LEAD PHASE-DOWN CONTROL OPTIONS

This socio-economic analysis (SEIA) was prepared by James F. Nicolling, Management Consultants Ltd., who undertook this work exclusively for and in accordance with the guidelines for analysis as laid down by Treasury Board. The project was supervised by Mr. John McMillan (principal author), Mr. Bruce, Mr. W. Wong and Mr. L. Struthers. It was executed under contract to Environment Canada and draws upon data and information supplied by the Department. The analysis also incorporates findings of other Environment Canada conducted studies and of submissions made by industry and other interested parties.

This SEIA has been reviewed by the Environmental Protection Service, Environment Canada, and by the Technical Advisory Board on Impact Assessment, Treasury Board of Canada, and approved for publication.

External Strategies Branch
Environmental Protection Service
Environment Canada

February 1984

FOREWORD

This socio-economic analysis (SEIA) was prepared by James F. Hickling, Management Consultants Ltd., who undertook the work necessary to meet the guidelines for analyses as laid down by Treasury Board. The project team consisted of Mr. John McMullen (principal author), Mr. Ahuja, Mr. W. Wong and Ms. L. Struthers. It was executed under contract to Environment Canada and draws upon data and information supplied by the Department. The analysis also incorporates findings of other Environment Canada consultant studies and of submissions made by industry and other interested parties.

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EXECUTIVE SUMMARY

Introduction

The Clean Air Act, which was promulgated on November 1, 1971, relates to ambient air quality and to the control of air pollution. Under this Act, regulations were issued for lead-free gasoline, effective July 1, 1974, and for leaded gasoline, effective January 1, 1976. The latter prescribe a maximum permissible concentration of lead in leaded gasoline of 0.77 grams per litre. Concern for environmental quality has been the basis for further assessment of automotive lead emissions and of possible means to reduce these emissions. The proposed regulations will become effective January 1, 1987.

This SEIA on lead phase-down control options complies with the requirements of the Federal Government's Socio-Economic Impact Analysis policy as contained in Chapter 490 of Treasury Board of Canada's Administrative Policy Manual.

Health and Lead-in-gasoline

Health and Welfare Canada has determined from recent studies that adverse health effects can occur at blood lead levels of 20-30 ug/dL. Furthermore, these studies indicate that:

- ° significant numbers of Canadian children could have blood lead levels in this range and could therefore be at risk; and
- ° gasoline lead contributes an estimated 30-35% of the lead in the blood of urban adults. The proportion of gasoline lead in children's blood may range from 30-40%.

Health and Welfare Canada has therefore concluded that a reduction of automotive lead emissions should significantly decrease lead uptake and, consequently, the blood lead levels in Canadians.

Control Options

Six control options (including 2 lead-trap options) to reduce automotive lead emissions have been investigated and compared to the base case of 0.77 g/L (Option 1, status quo). These control options involve either reducing the concentration of lead in leaded gasoline to:

- ° 0.29 g/L - Option 2
- ° 0.15 g/L - Option 3
- ° 0.0 g/L - Option 4
- ° 0.0 g/L, except 0.15 g/L for heavy-duty trucks, - Option 5

or reducing the lead concentration in automobile exhaust emissions by:

- ° the installation of lead traps on new vehicles designed to run on leaded gasoline, 1987 and beyond - Option 6(a); or
- ° the installation of lead traps on new vehicles, as well as the retrofit of lead traps on existing leaded gasoline vehicles - Option 6(b).

Two additional methods of decreasing automotive lead emissions that are discussed briefly in this SEIA, but excluded from detailed analysis, are:

- ° the use of a special excise tax to reduce or eliminate the price differential between leaded and lead-free gasoline, thereby reducing or eliminating the current savings to consumers who misfuel vehicles designed to operate on lead-free fuel with cheaper leaded fuel. In theory, this approach should decrease the sales ratio of leaded to lead-free gasoline; and
- ° a "pool" approach to regulating the lead content of motor gasoline by averaging the lead content of the total lead-free and leaded gasoline production.

Neither of these additional methods were addressed in Environment Canada's February 1983 report entitled "Control Options for Lead Phase-down in Motor Gasoline" and, therefore, industry and other parties have not had the opportunity to comment. Furthermore, as discussed in this SEIA, a control

option based upon an excise tax or price strategy has a number of inherent problems, while the pool concept is, among other considerations, subject to legal interpretation with respect to existing regulations. Such an interpretation is beyond the scope of this SEIA.

Methodology

The aim of the control options is a reduction of the human lead burden through a reduction of automotive lead emissions. It is not possible to assign a monetary value to human health and therefore a benefit-cost analysis could not be undertaken. Consequently, a cost-effectiveness measure is employed to determine the net benefit or cost per tonne of reduced lead emissions realized under each control option.

Numerous studies submitted by consultants and other parties, analyses conducted internally by Environment Canada, and the process of review and comment by industry have generated divergent estimates for benefits, costs and other effects that are associated with the various control options. In certain instances, where there are insufficient data or information upon which to select one particular estimate from among those presented, a range of estimates is provided; the most outstanding example of this is in the area of refinery capital and operating costs. As a result, the net benefit or cost for most options is presented as a range rather than a single estimate. Although this approach does not define the exact impact of each option, it nevertheless establishes their relative order of magnitude.

Option 1 (0.77 g/L, status quo), with a market share projection of 70% lead-free and 30% leaded gasoline, is regarded as the baseline. Estimates of benefits, costs, volumes, and lead emissions for Options 2-6 are given in relation to Option 1.

Allocative Benefits and Costs

Those control options that involve a reduction or elimination of lead in gasoline result in:

- ° increased refinery capital and operating costs due to increased processing requirements; and
- ° decommissioning costs due to the closure and dismantling of lead-additives manufacturing plants.

Options 6(a) and (b) give rise to direct consumer costs as a result of the installation of lead traps on vehicles designed to run on leaded gasoline.

The ranges of refinery capital and operating costs shown under most of the control options reflect the different assumptions made by the originators of those cost estimates. Environment Canada's minimum cost estimates are premised upon utilization of an isomerization refining process, gasoline octane levels lower than those currently provided by industry, and existing but not fully utilized lead-free capacity in the refinery industry. The maximum estimates of refinery costs, given by the Petroleum Association for Conservation of the Canadian Environment (PACE), are based on existing, or conventional, refinery process technology and current market octane levels.

Complete confidence cannot be placed in either of the two extremes; the former because it is based upon a refinery process technology as yet untried in Canada and octane levels that are contested by industry, the latter because it is suspected that industry cost estimates included lead-free capacity that will be needed because of market demand even without changes to the present regulations. The cost ranges in Options 2, 3 and 4 are narrowed considerably by adjusting industry estimates to reflect existing lead-free capacity and only incremental capacity requirements beyond 1987, as well as in Option 4 by Environment Canada's estimates for a more costly recycle isomerization process which increases the gasoline pool octane level. However, further narrowing of the ranges was not possible because more precise estimates of refinery capital and operating costs were not available.

The allocative benefits produced by the control options consist of:

- ° a reduction of automotive lead emissions (Options 2-6); and
- ° fuel economy and maintenance savings (Options 4 and 5).

Fuel economy and maintenance savings are achieved only with Options 4 and 5 (lead-free gasoline). It has been assumed that 2.8% average improved fuel economy and \$1/1000 km maintenance savings would result from the use of vehicles with catalytic converters that operate on lead-free fuel compared to similar vehicles without catalytic converters that run on leaded fuel.

Non-allocative Effects

Maintenance savings under Options 4 and 5 would impact specifically on the spark plug and muffler system segments of the automotive replacement parts market. It is estimated that spark plugs account for 4% and muffler systems for 7.5% of the value of manufactured goods in the Canadian replacement parts market. A consultant's study indicates that six years after the implementation of a lead-free gasoline regulation, these segments would experience a 10% and 15% decline of sales, respectively. When considering the impact of a lead-free control option, it is important to realize that the automotive replacement parts market, which is experiencing rapid technological change, consists of large manufacturing firms with diversified product lines. At the retail level, the impact of a lead-free option would be diffused unevenly over similarly diversified outlets. Garages that depend on tune-up work for a portion of their revenue and specialty muffler shops would be the most affected.

Reduced demand for lead additives will result in a corresponding decline in the demand for primary (as opposed to secondary/recycled) refined lead. In 1981, lead-additives manufacture accounted for about 6% of total Canadian primary refined lead production; under Option 1 (status quo) and Options 6 (a) and (b), this percentage would decline to an estimated 4% by 1990. Under Options 2, 3, 4 and 5, Canadian production of primary refined lead accounted for by lead additives would decline to 1.5%, 0.8%, 0.0% and 0.0%, respectively, by 1990.

Closure of one of the two lead-additives manufacturing plants is projected under Options 2 and 3, and of both plants under Options 4 and 5. Both plants are expected to operate under Options 1 and 6.

The net impact upon employment varies according to each option and according to which refinery processing scenario is used (e.g., Environment Canada's estimates based upon single isomerization or recycle isomerization, or PACE's maximum refinery cost estimates). Under Option 2, loss of jobs (158) in the lead-additives industry would be greater than increased employment (100) realized in the petroleum refining industry. Under Options 4 and 5 (with minimum refinery cost estimates) job losses (337) would still be greater than the increase in permanent refinery positions (250). However, refinery jobs needed for lead-free production at higher octane levels would exceed jobs lost (a range of 500-1000 additional positions vs 337 lost).

Few data exist with which to determine the impact upon employment of pre-regulation refinery construction. One estimate for a lead-free case at maximum refinery costs calls for about 4000 person-years employment during the 3-year development and implementation period.

Balance of Payments

Canada's balance of payments may be affected due to crude imports needed to offset refinery energy penalties incurred for Options 2 to 5. However, the amount of this increase and the impact upon Canada's stated target of crude oil self-sufficiency by 1990 are difficult to assess for each option (and for each cost estimate within those options) because of the non-uniform assumptions incorporated and the absence of detailed calculations.

Distribution of Income

The impact upon distribution of income is difficult to determine for the same reason noted in Balance of Payments above. A rough indication is provided by calculating the cents-per-litre impact of the net benefits or costs of each option. These range from a savings of 0.02 ¢/L under a lead-free option at minimum refinery costs (with the costs spread over total gasoline demand) to an increase of 0.74 ¢/L for leaded gasoline under Option 3 (0.15 g/L) at maximum refinery costs (with costs allocated to only leaded gasoline production from 1987 to 2006).

Cost-effectiveness of Control Options

Table A presents a summary of the lead-emission reductions and net benefits or costs generated by each option. With this information the cost-effectiveness of each option is calculated on a dollars (benefit/cost) per tonne (reduced emissions) basis. The costs are associated with refinery capital and operating expenditures, decommissioning of lead additives plants and lead-trap installation. The benefits are those associated with fuel economy and maintenance savings.

TABLE A COST-EFFECTIVENESS OF LEAD PHASE-DOWN CONTROL OPTIONS, 1987-2006
(Present Value, 1983 Dollars)

Option	Emission Reduction ^a (t x 10 ³)	Net Benefit or (Cost) ^b (\$ x 10 ⁶)	Benefit or (Cost) Per Tonne Reduction of Lead Emissions (\$/t)
1. 0.77 g/L Status Quo	-	-	-
2. 0.29 g/L			
-E.C. Minimum ^c	71.8	(114)	(1,590)
-PACE Maximum ^d	71.8	(452)	(6,300)
-PACE Adjusted ^e	71.8	(227)	(3,160)
3. 0.15 g/L			
-E.C. Minimum	93.0	(187)	(2,010)
-PACE Maximum	93.0	(1,438)	(15,460)
-PACE Adjusted	93.0	(721)	(7,750)
4. Lead-free			
-E.C. Minimum	115.1	105	910
-E.C. Recycle	115.1	(17)	(150)
-PACE Maximum	115.1	(1,681)	(14,605)
-PACE Adjusted	115.1	(660)	(5,735)
5. Lead-free Except 0.15 g/L for Heavy Trucks			
-E.C. Minimum	111.5	72	645
-E.C. Recycle	111.5	(50)	(450)
-PACE Maximum	111.5	(1,714)	(15,370)
-PACE Adjusted	111.5	(693)	(6,215)
6. Lead Trap			
(a) New Vehicles	60.7	(280)	(4,850)
(b) New & Retrofit	76.9	(660)	(8,580)

^a Total automotive lead emission reductions from 1987 to 2006, relative to emissions under the status quo (Option 1).

^b Cost includes capital construction costs from 1984 to 1986.

^c Environment Canada cost estimate.

^d Industry cost estimate.

^e Industry cost estimate adjusted to reflect existing lead-free refinery capacity and only incremental increase in refinery capacity after 1987.

1.0 INTRODUCTION

1.1 Purpose

Previous federal government regulations restricting the lead content of motor gasoline resulted from concern with the effects of lead emissions upon the health of Canadians. This continuing concern for health is the basis for Environment Canada's current assessment of various control options which are designed to decrease further automotive lead emissions.

The intent of this document is to assess the effects of the proposed control options in an objective fashion, taking into account, where feasible, information from various sources and evaluating it in terms of current dollars, updated forecasts, and other assumptions.

1.2 Lead Emissions to the Environment

The automotive industry accounts for the vast majority of lead used in Canada. Of the 106,800 tonnes of lead consumed during 1980, approximately 60% was used in the production of acid-storage batteries and 13% in the manufacture of chemical compounds. Lead additives accounted for 80% of the lead consumed in the manufacture of chemical compounds (1). *∴ it's a big industry that can be affected*

In 1970, about 17,500 tonnes of lead were emitted to the atmosphere in Canada from all sources. In 1978, the latest year for which inventory data are available, 14,600 tonnes of lead were emitted (2). Leaded gasoline accounted for about 73% (12,800 tonnes) and 63% (9200 tonnes) of total atmospheric lead emissions in 1970 and 1978, respectively, with the balance resulting from smelting operations, fuel combustion, lead-containing product manufacture, and other sources. By 1982, lead emissions from leaded gasoline had declined to an estimated 6900 tonnes, due primarily to the introduction of lead-free gasoline in the mid-1970s, and its subsequent growth in sales.

In Canada, 75% of the lead is emitted in the southern regions of the country where 93% of Canadians live.

1.3 Lead Additives in Gasoline

Engine "knock" is the premature combustion of the air-fuel mixture within an engine cylinder; it wastes energy that otherwise would be available

to power motor vehicles and can cause damage to the engine. Engine knock can be eliminated by increasing the gasoline's octane number either through the use of lead additives (tetraethyl and tetramethyl lead) or by a greater utilization of high-octane hydrocarbons produced in the refining process.

Gasoline lead additives were first introduced in the 1920s in order to improve automobile engine performance. In the early 1970s, the automotive industry was required by law to reduce the concentration of hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x) in exhaust emissions. Catalytic converters, which remove HC and CO from the engine exhaust, were first installed on 1975-model cars. However, lead "poisons" the catalyst, thereby destroying the converter's emission control capability. The petroleum refining industry therefore had to introduce "lead-free" gasoline to ensure the long-term, effective operation of catalytic converters.

1.4 Leaded Gasoline Regulations under the Clean Air Act

1.4.1 Clean Air Act. The Clean Air Act, proclaimed on November 1, 1971, provides the basis for the federal government's air pollution control regulations. The Act has three primary objectives, the first being the protection of the health of Canadians from air pollutants. To this end, federal regulations have been promulgated which limit the emission to the atmosphere of hazardous pollutants, including lead, mercury, vinyl chloride, and asbestos, from specific industrial sectors.

The second objective of the Clean Air Act is to promote a uniform national approach to the control of air pollutants. In order to achieve this, and to provide appropriate leadership by the federal government, the Act permits the issuance of air emission guidelines which, if adopted by a province as regulations, are enforceable by that province.

The Act's third objective is to provide the mechanisms and institutions needed to ensure that all measures to control air pollution can be effectively undertaken. In this regard, it is recognized that the provinces have a direct responsibility for the control of air pollution and that co-operative efforts are required between both provincial and federal authorities.

Three sections of the Clean Air Act are important to the lead phase-down issue. Section 2 defines air pollution as a condition of the ambient air, arising in whole or in part from the presence of one or more contaminants, that:

- endangers the health, safety or welfare of persons;
- interferes with normal enjoyment of life or property; and
- endangers the health of animal life or causes damage to plant life or to property.

Under Sections 22 and 23 of the Act, the Governor General in Council may make regulations prescribing the maximum concentration of an additive in any fuel that is consumed or intended for consumption in Canada. Section 22 states that no person shall produce for use or sale in Canada, or import into Canada, any fuel that contains any element or additive in a concentration that exceeds the concentration prescribed, with respect to that element or additive, by the Governor General in Council under Section 23.

1.4.2 Current Regulations Relating to Lead in Gasoline. The Leaded Gasoline Regulations, which came into effect January 1, 1976, prescribe a maximum permissible lead concentration of 0.77 grams per litre of "leaded" gasoline. Regulations restricting lead-in-gasoline concentrations in a number of other countries are shown in Table 1. Table 2 shows the lead content of the total gasoline pool for the U.S. and for Canada.

The Lead-free Gasoline Regulations, published in October 1973 and effective July 1, 1974, prescribe a maximum permissible concentration of 0.013 grams of elemental lead per litre of "lead-free" gasoline.

1.5 Lead Emissions Abatement Control

In principle, reductions of lead emissions to the atmosphere from motor gasoline may be achieved through:

- a further reduction of the allowable concentration of lead in gasoline;
- a reduction of the ratio of leaded to lead-free gasoline sales volumes; and
- the capture of lead particles in exhaust emissions by means of lead traps.

Based upon these alternatives, a number of regulatory and policy measures were identified by Environment Canada. Numerous engineering consultant studies were subsequently commissioned to investigate the allocative costs and benefits and the non-allocative effects of these measures.

TABLE 1 MAXIMUM ALLOWABLE LEAD CONTENT OF GASOLINE IN DIFFERENT COUNTRIES (FEBRUARY, 1983)

Country	Grams Lead per Litre	Notes
<u>Europe</u>		
(a) EC Member States		
Belgium	0.4	
Denmark	0.4 premium 0.15 regular (0.15 premium from July 1984)	
France	0.4	
FR Germany	0.15	
Greece	0.4	
Ireland	0.4	
Italy	0.4	
Luxembourg	0.4	
Netherlands	0.4	
	(0.15 from 1986)	
UK	0.4 (0.15 from January 1986)	
(b) Other Countries		
Austria	0.4 premium 0.15 regular (0.15 premium from July 1983)	
Finland	0.4	
Norway	0.4 premium 0.15 regular (0.15 premium from Sept. 1983)	
Portugal	0.635	
Spain	0.65 98 RON* 0.6 96 RON 0.48 90 RON	
Sweden	0.15	
Switzerland	0.15	
Yugoslavia	0.6	
<u>Rest of World</u>		
Australia	0.84	commercial practice
except:		
(i) Sydney, Newcastle and Wollongong Districts of NSW	0.4	
(ii) Victoria	0.3	legal requirements
(iii) Tasmania	0.45	
Canada	0.77	legal requirement
Japan	0.31 premium 0.02 regular unleaded	advisory
New Zealand	0.84 (0.45 from 1984)	commercial practice advisory
South Africa	0.84	advisory
USA	0.29 0.013 unleaded	legal requirement

* RON = Research Octane Number
Source: The Associated Octel Co. Ltd.

TABLE 2 LEAD CONTENT OF GASOLINE POOL, 1982

Country	Grams Lead per Litre
USA	0.16
Canada	0.28

In February 1983, a report entitled "Control Options for Lead Phase-down in Motor Gasoline" was published by the Environmental Protection Service (2), together with a list and summary of consultants' studies. Copies of the reports have been available from Environment Canada offices upon request. An invitation was extended to all those concerned with the lead-in-gasoline issue to examine these documents and to provide Environment Canada with comments which, it was indicated, would be taken into consideration during the development of amended Leaded Gasoline Regulations.

The control options assessed in this SEIA are essentially the same as those described in the Control Options Report; namely:

- Option 1:** maintain the status quo by allowing the addition of 0.77 g Pb/L to leaded gasoline.
- Option 2:** promulgate a leaded gasoline regulation restricting the concentration of lead in leaded gasoline to 0.29 g/L, which is similar to the quarterly-average limit announced by the U.S. Environmental Protection Agency (EPA) on Oct. 29, 1982.
- Option 3:** promulgate a regulation restricting the concentration of lead in leaded gasoline to 0.15 g/L, which is similar to the limit being adopted by most countries in the European Economic Community (EEC).
- Option 4:** promulgate a regulation which would prohibit the addition of lead additives to gasoline. This is the lead-free option.
- Option 5:** promulgate a regulation that requires the use of lead-free gasoline for all automotive vehicles except heavy trucks. Heavy trucks would be permitted to use leaded gasoline with a lead concentration of 0.15 g/L which truck manufacturers state is necessary to prevent excessive valve wear that may occur with lead-free gasoline.

- Option 6:**
- a) promulgate a regulation that would require the installation of lead traps on all vehicles manufactured after 1986 designed to run on leaded gasoline. Automotive exhaust emission standards for lead would then be set in terms of grams of lead per kilometre.
 - b) as for 6(a), but on new vehicles after 1986 and the retrofit of lead traps on existing vehicles not designated as lead-free.^a

The regulatory options identified fall under one of two basic legislative approaches open to the federal government to control automotive lead emissions:

- Options 1-5: use the authority of the Minister of the Environment under the Clean air Act to reduce or eliminate the use of lead in gasoline;
- Option 6: use the authority of the Minister of Transport under the Motor Vehicle Safety Act to regulate the maximum allowable lead emissions from vehicle exhausts.

Two additional control measures have been identified; however, these are not fully explored within this SEIA and are not entertained as viable options at this time. The first, as proposed by the Economic Council of Canada, is an additional excise tax upon leaded gasoline to eliminate the current price differential between leaded and lead-free gasolines and the present economic incentive to motorists to use leaded fuel, thereby encouraging drivers to switch to lead-free fuel. A study of the feasibility of such an approach was commissioned by Environment Canada and carried out by Econosult Inc. (3). Although the consultant concluded that an excise tax strategy combined with the regulation of gasoline prices may theoretically decrease the demand for leaded

^a The lead-trap option is shown in two scenarios because of the significant difference in both emissions reduction and costs arising between 6(a) (which applies to only new vehicle sales) and 6(b) (retrofit as well). The decision to introduce this variation of the lead-trap option was made following the publication of the Control Options Report and resulted from discussions with the Environmental Protection Service.

gasoline, a number of questions have been raised regarding the viability of this approach; this tax strategy has therefore been excluded from consideration in this report (refer to Appendix D).

A second control measure, raised by several industry representatives, involves the control of lead in gasoline by means of a regulation limiting the concentration of lead in the total gasoline pool. This approach is further discussed in Appendix D; the merits afforded industry by such a "pool" regulation are presented, as well as the reasons why it is not included within this analysis.

1.6 Study Methodology

This report provides an analysis of the potential allocative costs and benefits and non-allocative effects of each of the proposed control options. Where possible, resource allocation effects should be measured and shown in terms of benefit-cost analysis; however, this type of analysis is not feasible in this instance because the benefit in question - the benefit to the health of Canadians resulting from a reduction of lead emissions - cannot be assigned a monetary value.

The alternative approach, and the basis of this SEIA, is to assess each option according to the cost-effectiveness of that option. The measure of cost-effectiveness of each lead phase-down option under consideration will be the net benefit or cost per tonne of lead emissions reduction produced by that option.

1.7 SEIA Structure

An assessment of the impact of lead upon human health, with particular reference to automotive lead emissions, is presented in Section 2. Section 3 gives a brief discussion of the gasoline sales forecast used as the basis for analyses in this report, a comparison of this forecast with those used in previous studies and an estimate of the air lead emissions expected under a maintenance of the status quo.

The allocative costs and benefits are investigated in Section 4. Various assumptions incorporated in the analyses are identified and explained; costs (refinery capital and operating, lead additive plant decommissioning and lead-trap costs) and benefits (emission reductions, fuel economy, and mainten-

ance savings) are summarized. The cost-effectiveness measures of each option are presented.

Non-allocative effects (including impacts upon employment, market structure, and the primary lead, lead additive manufacturing, and automotive aftermarket industries) are treated in Section 5, along with an identification of the effect upon distribution of income, expressed as a cents-per-litre change in the price of gasoline resulting from each of the control options.

The report concludes with a review of the cost-effectiveness measures, major qualifications, and potential problems which should be considered when evaluating the viability of the proposed lead phase-down control options.

2.0 HUMAN EXPOSURE TO ENVIRONMENTAL LEAD

This section, prepared by Health and Welfare Canada, deals with lead toxicity, environmental levels of lead, human exposure to lead, and evidence of the contribution of lead in gasoline to lead in human beings. It is concluded that a reduction of automotive lead emissions should significantly lower the uptake of lead and the blood lead levels in the Canadian population. Reduction of lead exposure is desirable for the following reasons:

- lead has no beneficial physiological function in man;
- recent studies indicate that adverse health effects can occur at blood lead levels of 20-30 $\mu\text{g}/\text{dL}$;
- large amounts of lead are released into the atmosphere from leaded gasoline;
- gasoline lead contributes significantly to the concentration of lead in blood. The Turin Isotopic Lead Experiment showed that gasoline lead contributed a minimum of 24% and 12% of the blood lead levels of Turin and rural residents, respectively;
- the above statements, when applied to available Canadian data, show that a significant number of Canadian children could be at risk.

2.1 Lead Toxicity

Lead is potentially toxic in most, if not all, of its chemical species and physical states: elemental lead, inorganic and organic forms, and as a gas (vapour), respirable particles, liquid and solid. Lead is particularly hazardous since it is cumulative and it produces many and severe toxic effects. Lead toxicity may be acute, chronic, or subchronic; carcinogenicity, teratogenicity, mutagenicity and reproductive damage potentials have been reported. The risk of frank lead poisoning or incipient ill-health must take into consideration the many sources of exposure that exist and the significance of each individual contribution to the total lead burden (4). The particular vulnerability to lead poisoning of young children must be emphasized (4).

Signs and symptoms of chronic and subchronic lead poisoning include anorexia, constipation, abdominal cramp (colic), pallor (anemia), headache, irritability, fatigue, and peripheral neuropathy (wrist drop, ankle drop) (4). In severe poisoning episodes, impaired kidney function, heart damage, mental retardation, convulsions, coma, encephalopathy and death are found (4).

In young children, relatively low blood lead levels cause neurological and behavioural changes: hyperactivity, lower learning capacity, reduced attention span, fearfulness, and general regression, among others (5,6,7). Other studies prove that lead inhibits the activity of the brain enzyme dihydropteridine reductase, essential for the synthesis of several neurotransmitters (8,9).

Ordinarily, the above symptoms are not noted until a fairly substantial lead exposure has occurred which can be confirmed by blood lead determinations. A blood lead level of 30 $\mu\text{g}/\text{dL}$ has customarily been considered the "cut-off" in diagnosing lead poisoning; more recent studies indicate, however, that subtle adverse health effects occur at lower blood lead levels. Some of these adverse effects require the use of special investigative techniques; the toxic changes may not be apparent to the unskilled observer. Examples of changes noted are altered brain metabolism (including neurotransmitters), neurobehavioural alteration, and subcellular biochemical changes such as heme formation and RNA binding (10).

The cellular changes indicate that impaired heme synthesis, signified by increased EP (erythrocyte protoporphyrin) levels, can be detected at a blood lead level of 15-18 $\mu\text{g}/\text{dL}$ (9). Heme is an essential component of hemoglobin, which is responsible for the transport of oxygen by the red blood cells. Lead has also been shown to bind with RNA (ribonucleic acid) at pH and temperature conditions found in living cells. Transfer RNA (tRNA) and messenger RNA (mRNA) have important roles in the synthesis of protein.

The more recent data noted above, which indicate that adverse health effects can occur at lead levels of 20-30 $\mu\text{g}/\text{dL}$, provide added impetus for reducing lead exposure.

2.2 Levels of Lead in the Environment

2.2.1 Air. The exhaust emissions from engines using leaded gasoline are the greatest source of atmospheric lead in Canada. In 1978, gasoline lead additives accounted for 9160 tonnes, or 63%, of all lead released to the atmosphere in Canada, and 88% of lead emissions when copper, nickel, iron, steel and lead production point sources are excluded (2).

The concentrations of atmospheric lead to which Canadians are exposed depend on the proximity of their homes to roadways and the amount of time spent

TABLE 3 SUMMARY OF LOWEST BLOOD LEAD LEVELS ASSOCIATED WITH SPECIFIC BIOLOGICAL CHANGES IN CHILDREN

µg/dL	Biological Changes
10	ALAD (delta aminolevulinic acid dehydratase - precursor of heme) inhibition
15	Increased plasma bipterins (neurotoxicity)
15-18	Increased EP (erythrocyte protoporphyrin) (onset of hematologic response)
13-32	Continuum evidence of behavioural changes (decreased I.Q., hyperactivity, tension, anxiety, etc.)
40-50	Anemia
50-60	Peripheral neuropathy (functional disturbance in the peripheral nervous system)
80-100	Encephalopathy (disease of the brain)

near major roadways. The National Air Pollution Surveillance (NAPS) network monitors lead concentrations in ambient air at more than 90 sites across Canada. However, human exposure to lead in ambient air is likely underestimated by the NAPS network since many of the samplers are sited on top of buildings, often 10 to 20 metres above ground level. Several monitoring surveys have compared lead levels at curbside locations with the levels from nearby NAPS samplers (Table 4). Curbside lead concentrations were found to be 1½ to 4 times higher than corresponding NAPS measurements (2,11,12). In 1982, the annual geometric mean lead concentration from 80 stations was 0.27 µg/m³ (13). The lowest and highest annual mean values, 0.03 µg/m³ and 0.79 µg/m³, were recorded in a residential area of Toronto and a commercial area of Montreal, respectively. Data from NAPS samplers indicate that urban residents would be exposed to 0.27-1.08 µg Pb/m³ (annual geometric mean to 4 times this value).

2.2.2 Drinking Water. In a recent survey, lead levels were determined in tap water samples collected from 71 municipalities across Canada, representing the water supplied to 55% of the Canadian population (14). Samples were taken after the taps were flushed at their maximum flow rate for 5 minutes. The

TABLE 4 COMPARISON OF NAPS AND CURBSIDE LEAD CONCENTRATIONS ($\mu\text{g}/\text{m}^3$)

Date	Location					Reference
	Toronto	Montreal	Ottawa	Edmonton	Vancouver	
	60401	50108	50109			2
Station	60403					
Height above street level	20 m	14 m	3 m			
1974 ^a	1.22	1.03	3.78			
1975 ^a	0.91	0.86	2.62			
1976 ^a	-	0.88	2.26			
1977 ^a	-	0.69	1.61			
1978 ^a	0.66	0.55	1.35			
Station	60401		60101			11
Height	20 m		16 m	curbside		
	0.34		0.54	0.72		
	0.3		0.43	0.68		
Station	60417	50104	60104	90122	00109	00104
Height	16 m	13 m	3.5 m	4 m	1 m	1 m
		1 m			1 m	2 m
	0.27	0.40	0.29	0.93	0.13	0.46
					0.25	0.47
					0.52	0.89
					1.80	0.36
						1.64

^a Annual geometric means

^b Mean values, Oct.-Nov. 1980

median concentration was $<1 \mu\text{g/L}$, with a range of <1 to $80 \mu\text{g/L}$. The results were very similar to a previous national survey of lead levels in tap water (15).

2.2.3 Soil, Dirt and Dust. Lead reaches soil by the natural weathering of rocks, through atmospheric deposition, and from local sources such as mine wastes. High lead levels in soils near urban centres have been related to traffic density, and proximity to roadways and industrial point sources (16). The average lead concentration in Canadian soils has been reported to be $12 \mu\text{g/g}$. Levels of lead in soils at 14 sites in Winnipeg were found to range from 40 to $2600 \mu\text{g/g}$ (17). Soils in other urban areas in Canada were found to contain 125 to $887 \mu\text{g Pb/g}$ (16).

A study of the lead content of street dust revealed the following average concentrations: Vancouver (residential) - $6000 \mu\text{g/g}$; Richmond, British Columbia - $40,000 \mu\text{g/g}$; Toronto (urban) - $1000 \mu\text{g/g}$, ranging from 500 to $1561 \mu\text{g/g}$; Toronto (smelter area) - $5830 \mu\text{g/g}$, ranging from 580 to $39,500 \mu\text{g/g}$; Toronto (industrial) - $67,800 \mu\text{g/g}$ (16,18).

Household dust was reported to contain mean lead levels of $845 \mu\text{g/g}$, ranging from 350 to $2010 \mu\text{g/g}$ (8 homes, Toronto, urban); $2060 \mu\text{g/g}$, ranging from 470 to $8400 \mu\text{g/g}$ (16 homes, Toronto, smelter area); $279\text{--}11,000 \mu\text{g/g}$ (United States); and a mean of $1260 \mu\text{g/g}$, ranging from 39 to $30,060 \mu\text{g/g}$, in 977 samples from 10 towns in Great Britain (4,18,19).

2.2.4 Food. All food contains naturally derived lead. Other sources, including lead from atmospheric fallout or the use of lead-soldered cans, may contaminate foods. Since 1975, Health and Welfare Canada has monitored the lead content in canned food. Table 5 displays the levels of lead found in various foods.

The concentration of lead in most uncanned foods ranges from 0.02 to $0.10 \mu\text{g/g}$; the levels detected in most canned foods are significantly higher and contribute an estimated 13-22% of the total dietary intake of lead for children and adults (20). A recent report calculated that atmospheric fallout contributed $13 \mu\text{g/day}$ of the lead in an average adult diet in the United Kingdom (21).

Except for milk products, baby foods are not packaged in lead-soldered containers and therefore have only trace amounts of lead. Table 6

TABLE 5 LEVELS OF LEAD IN FOOD, AS CONSUMED (REF. 20) (ESTIMATED FROM CANADIAN DATA EXCEPT WHEN INDICATED BY *)

		Average Lead ($\mu\text{g/g}$)	
		Uncanned	Canned
1.	Dairy products:		
	milk, cream*, yogurt*	0.02	
	evaporated milk		0.04
	ice cream, butter, margarine	0.05	
	cheese	0.24	
2.	Meat, poultry and fish:		
	beef, pork, liver, poultry	0.08-0.10	
	cold cuts, veal, lamb, fish*, eggs	0.05	
	meat and poultry (prepared)		0.25
	tuna		0.26
	salmon		0.16
	fish (other, except shellfish)		0.10
3.	Cereals:		
	bread, cakes*, crackers*, breakfast cereals	0.04-0.05	
	flour (wheat, corn, etc.)	0.08	
	rice	0.05	
	pasta	0.05	0.10
	corn	0.03	0.36
4.	Potatoes:		
	potatoes (prepared)	0.06	0.12
	sweet potatoes*, yams*	0.08	0.25
	chips*	0.16	
5.	Leafy vegetables:		
	cabbage	0.05	
	celery, cauliflower*, broccoli	0.03-0.04	
	asparagus	0.03	0.13
	lettuce and other greens	0.07	0.13
	mushrooms	0.04	0.18
6.	Other vegetables:		
	beans, peas	0.03	0.13-0.16
	vegetable soups		0.06
	beets, carrots, onions	0.05-0.07	0.13-0.17
	turnips, parsnips	0.03	
7.	Fruit and fruit products:		
	citrus, plums*, prunes*, apricots*, other fruits	0.03	0.14
	grapes, cherries*, melon*	0.02	0.14
	bananas*, peaches, nectarines, pears	0.04	0.22-0.27

TABLE 5 LEVELS OF LEAD IN FOOD, AS CONSUMED (REF. 20) (ESTIMATED FROM CANADIAN DATA EXCEPT WHEN INDICATED BY *) (Cont'd)

	Average Lead (ug/g)	
	Uncanned	Canned
apples	0.14	0.17
berries	0.05	0.14
pineapple	0.05	0.19
citrus juice	0.03	0.10
apple juice, grape juice		0.08-0.09
cucumbers, eggplant, squash*	0.03	
tomatoes	0.04	0.25
tomato juice		0.20
tomato paste and puree		0.57
tomato soup		0.06
8. Oil and fats:		
peanuts, other nuts, peanut butter, salad dressings	0.05	
shortening and cooking oils*	0.02	
9. Sugar and preserves:		
sugar, artificial sweeteners	0.05	
syrup		0.17
molasses	0.41	
jam, jelly, honey, puddings	0.05	
pickles, vinegar	0.05-0.07	
chocolate bars	0.10	
candy other than chocolate	0.06	
10. Beverages:		
coffee, tea	0.03	
soft drinks		0.05
alcoholic drinks*	0.01	

* Estimated mainly from U.S. data, but includes some Canadian data.

presents the lead content of Canadian baby foods, determined by food monitoring programmes of Health and Welfare Canada (20).

Health and Welfare Canada has a cooperative programme with industry to reduce lead intake from canned foods (22).

2.3 HUMAN EXPOSURE TO LEAD

2.3.1 Blood Lead Levels in Canada. Measurement of the lead concentration in venous or capillary blood samples is the most widely used assessment of lead

TABLE 6 LEAD LEVELS IN INFANT FOOD IN CANADA (REF. 20)

	Average Lead Conc. (ug/g)
Prepared infant formula (canned)	0.03
Infant formula, powdered	0.01
Strained meats and meat dinners	0.03
Junior meats and meat dinners	0.03
Strained vegetables	0.04
Junior vegetables	0.03
Strained fruits and desserts	0.05
Junior fruits and desserts	0.04
Juices and drinks	0.05
Cereals	0.09
Evaporated and condensed milk	0.04
Milk, whole, 2% fat or skimmed	0.02
Table foods	0.07

in the body. Blood lead concentrations are influenced by short-term exposure (in the order of weeks), while lead concentrations in teeth and bones indicate long-term and possibly life-time exposure. Table 7 describes several studies conducted in Canada to determine blood lead levels.

A national survey of blood lead levels was conducted during 1978-79 as part of the Canada Health Survey (30). The overall distribution was not log normal as expected in such a survey (31). Similar distributions were found for each group studied, defined by sex, age, month of sampling, population of place of residence, province, occupational status or family income. Also, 27% of the observations were ≤ 1 ug/dL, an unusual characteristic which cast doubt on the validity of the results.

Blood lead levels in Canada appear to have declined over the past 10 years (Table 7). The most recent results, from a study in Toronto in 1982, indicate that 1% of children aged 0-4 years have blood lead concentrations greater than 30 ug/dL and 12% have concentrations greater than 20 ug/dL. If these results are representative of urban centres, then an appreciable number of children would be potentially at risk from lead exposure.

TABLE 7 BLOOD LEAD CONCENTRATIONS IN CANADA

Location; Date	Population Studied	Blood Lead Concentrations (ug/dL)				Reference
		Mean	Percent with:			
			≥ 20 ug/dL	≥ 30 ug/dL	≥ 40 ug/dL	
Toronto May-Dec 73	84 children (0-14 yr) close to smelter A	27			28% (summer)	18
	1041 children (0-15 yr) close to smelter B	28			13% (winter)	
	children (0-14 yr) similar socio-economic urban control group	19			1%	
Montreal August 73	16 families within 150 m of smelter A	31 (12-61)				23
	8 families, urban control group	19 (8-40)				
	712 children (0-6 yr) attending the Pediatric Outpatients Dept. of Montreal Children's Hospital				4.8%	
November 73	Follow-up study:					
	34 children who had ≥ 40 ug Pb/dL	48.4 (Aug.)				
	30 children who had "normal" blood levels	27.0 (Aug.)				
Halifax Summer 73	184 children (0-5 yr)		4%	1.1%		24 25
	642 random sample subjects	14.9				
	adults: 211 males (≥ 16 yr)	15.3				
Ottawa Jan-Apr 75	228 females (≥ 16 yr)	12.5				
	children: 124 males (≥ 16 yr)	17.7	33%	7.5%	0.5%	
	89 females (≥ 16 yr)	16.2				
Trail, B.C. Sept. 75 May 1975 May 1975	Near a large Pb-Zn smelter					26
	96 children, 1-3 yr	22			18.7%	
	113 grade 1 children	22			15.1%	
Nelson, B.C. Sept. 75 May 1975 May 1975	141 grade 9 children	11			1.4%	
	55 children, 1-3 yr	14			0	
	96 grade 1 children	14			2.1%	
Kamloops, B.C. May-Nov. 1977	103 grade 9 children	10			0	27
	2-3 yr (109 subjects; 55 M, 54 F)		2.2	0	0	
	4-5 yr, kindergarten (240 subjects; 136 M, 104 F)		4.9	0	0	
	9 yr, grade 3 (283 subjects; 155 M, 128 F)		4.4	0.7	0	
	12 yr, grade 6 (314 subjects; 150 M, 164 F)		8.2	0	0	
	total sample (946 subjects; 496 M, 450 F)		5.5	0.2	0	
		11.2 (median)				

TABLE 7 BLOOD LEAD CONCENTRATIONS IN CANADA (CONT'D)

Location; Date	Population Studied	Blood Lead Concentrations (µg/dL)				Reference
		Mean	Percent with:			
			≥ 20 µg/dL	≥ 30 µg/dL	≥ 40 µg/dL	
Toronto Oct. 1982	South Riverdale area	13.1 + 5.1				28
	1009 males	11.2 + 4.4				
	1250 females	12.1 + 5.1				
	total sample (2259)					
	0-4 yr (329 subjects)		11.8	0.9		
	5-9 yr (881 subjects)		3.9	0.1		
	10-14 yr (401 subjects)		5.0	0.7		
	15+ (643 subjects)		6.4	0.5		
	all (2254 subjects)		5.9	0.44		
Toronto Oct. 1982	Grade 1 children:					29
	South Riverdale (36 subjects)	11.8 + 0.7	5.6			
	South Riverdale (141 subjects)	12.0 + 0.4	6.4			
	adjacent to S. Riverdale (103 subjects)	10.3 + 0.4	0			
	W. Toronto, socioeconomically sim. to					
	S. Riverdale (103 subjects)	12.5 + 0.4	3.9			
	N. Toronto, socioeconomically diff. from					
	S. Riverdale (103 subjects)	11.2 + 0.3	1.0			
	all (486 subjects)		3.3			

2.3.2 Contribution to Lead Exposure from Various Sources. The relationship between lead exposure and blood lead concentration has received considerable attention recently. It is now believed that the relationship between the concentration of lead in air and in blood is curved (33,34). Similarly, curvilinear relationships have been observed between the concentration of lead in blood and in tap water (35), and between lead in blood and dietary lead intake (20,35). These relationships are of similar form and indicate that successive increments in exposure to lead result in progressively smaller contributions to blood lead concentrations (Figures 1 and 2).

In order to assess the relative contributions of the various sources of lead to the intake and uptake of lead, a balance scheme was constructed which took into account several sources of lead intake by humans (air, water, food, dust) and the respective absorption factors. Table 8 displays estimates of total exposure to lead made for four population groups. The exposure data used to construct the balance scheme are average values from Canadian data. Individual variations in exposure were noted, depending on locations of residence and work, lead concentration in tap water, the amount of canned food consumed, and activity. Smokers and heavy drinkers were not included; both these groups have been found to have higher blood lead levels in epidemiological studies (38,39). The absorption factors cited for inhaled and ingested lead were taken from several recent scientific reviews (18,36).

The amount of dust and dirt ingested (row 14, Table 8) was estimated for children exhibiting normal hand-to-mouth behaviour, such as sucking fingers and a variety of objects. These children have been estimated to ingest about 0.1 g of dust and dirt per day. Children exhibiting pica, the habit of swallowing non-food items such as soil and paint, have been estimated to ingest about 1 g of dirt and dust per day (19). These children were not considered in the Table 8, although they could ingest substantial amounts of lead by this route.

The estimated total daily uptake of lead (row 18, Table 8) was calculated to be 12 μ g and 17 μ g for rural and urban adults, and 33 μ g and 58 μ g for rural and urban children, respectively. The percentage contribution of air, water, food, dust and dirt to the total daily intake of lead was calculated (rows 19-22). For rural inhabitants, food is the major source of lead uptake; air and dust/dirt are minor sources for both adults and children. For urban residents, food, again, is the largest source of lead uptake, but air and dust are also major sources.

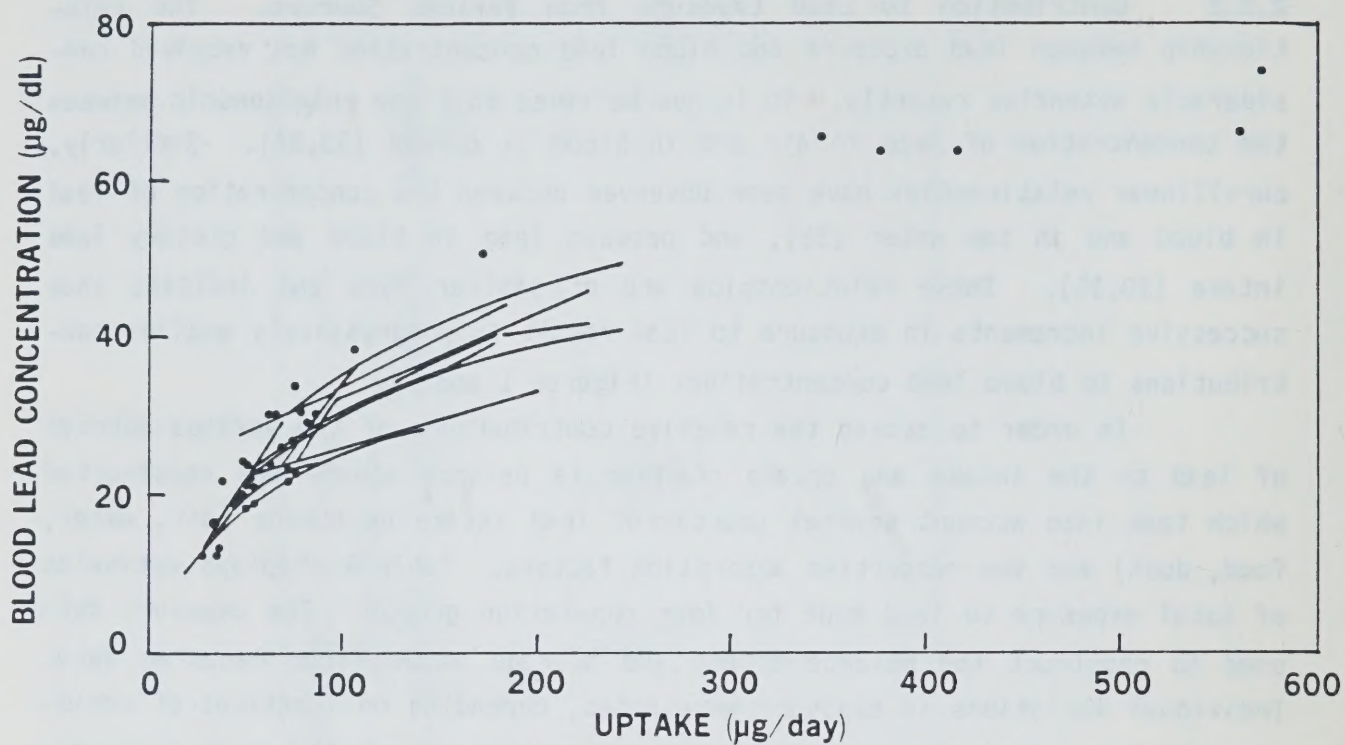


FIGURE 1 RELATIONSHIP BETWEEN BLOOD LEAD CONCENTRATION AND TOTAL UPTAKE FOR ADULTS (results of several studies) (4)

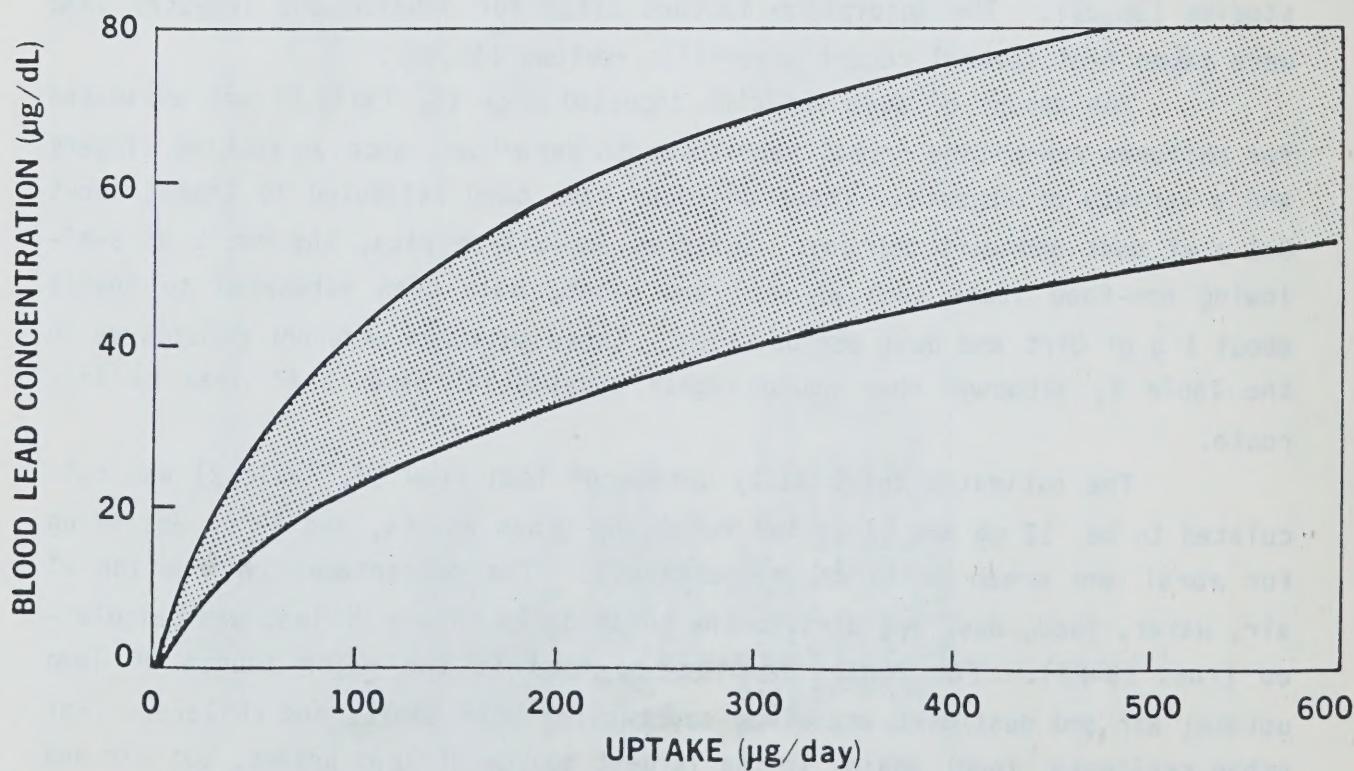


FIGURE 2 RELATIONSHIP BETWEEN BLOOD LEAD CONCENTRATION AND TOTAL LEAD UPTAKE FOR ADULTS, SHOWING THE RANGE OF INTERPRETATIONS POSSIBLE FROM FIGURE 1 (4)

TABLE 8 BALANCE SCHEME FOR INTAKE AND UPTAKE OF LEAD

	Urban		Rural	
	adults	children (1-3 yr)	adults	children (1-3 yr)
1. average air lead concentration ($\mu\text{g}/\text{m}^3$) ^a	0.54	0.54	0.10	0.10
2. volume of air inhaled (m^3/day)	20	6	20	6
3. intake of lead from air ($\mu\text{g}/\text{day}$)	10.8	3.2	2	0.6
4. percentage of lead absorbed in lungs ^b	40	40	40	40
5. total lead uptake from lungs ($\mu\text{g}/\text{day}$)	4.3	1.3	0.80	0.24
6. average tap water lead concentration ($\mu\text{g}/\text{L}$) ^c	1.0	1.0	1.0	1.0
7. volume of tap water consumed (L/day) ^d	1.4	0.6	1.4	0.6
8. intake of lead from tap water ($\mu\text{g}/\text{day}$)	1.4	0.6	1.4	0.6
9. intake of lead from food ($\mu\text{g}/\text{day}$) ^e	113	62	113	62
10. total intake of lead from water and food ($\mu\text{g}/\text{day}$)	114.4	62.6	114.4	62.6
11. percentage of lead absorbed in gut ^b	10	50	10	50
12. lead uptake from water and food in gut ($\mu\text{g}/\text{day}$)	11.4	31.3	11.4	31.3
13. average lead concentration in dust and dirt ($\mu\text{g}/\text{g}$) ^f	850	850	60	60
14. amount of dust and dirt digested (g/day) ^g	0.02	0.1	0.02	0.1
15. intake of lead from dust and dirt ($\mu\text{g}/\text{day}$)	17	85	1.2	6
16. percentage of lead absorbed in gut ^b	10	30	10	30
17. lead uptake from dust and dirt in gut ($\mu\text{g}/\text{day}$)	1.7	25.5	0.12	1.8
18. total lead uptake from lungs and gut ($\mu\text{g}/\text{day}$)	17.4	58.1	12.3	33.3
19. percentage daily lead uptake from: air	25	2	6	0.7
20. percentage daily lead uptake from: water	0.8	0.5	1	1
21. percentage daily lead uptake from: food	65	53	92	93
22. percentage daily lead uptake from: dust/dirt	10	44	1	5

^a For urban residents, twice the 1982 annual geometric mean concentration from NAPS samples was used, since it is thought that the NAPS data underestimate human exposure.

^b Reference 36.

^c Reference 14.

^d Reference 37.

^e Value based on the average total diet for males and females, and for 1-, 2- and 3-year-olds (reference 20).

^f References 18 and 36.

^g References 18 and 36.

Table 9 presents an estimate of the contribution of lead in gasoline to the daily uptake of lead. The percentage of lead in dust which originates from gasoline lead is presently unknown. Information on this subject should be available soon (39). In the meantime, a very conservative assumption is that 50% of lead in dust and dirt is derived from leaded gasoline (row 26, Table 8). In this case, it can be calculated that 17 μg (29%) and 5.8 μg (33%) of the daily lead uptake by urban children and adults, respectively, are derived from gasoline lead (rows 28 and 29). Estimates of lead uptake for adults and children exposed to various air lead levels are shown in Table 10.

In Canada, the Hazardous Products Act regulates the concentration of lead in paint, children's furniture and toys, and glazed ceramic ware. Since these are the only other significant sources of lead contamination in dust away from point sources such as smelters, it is not unreasonable to assume that more than 50% of lead in dust and dirt originates from leaded gasoline. The contributions from leaded gasoline were recalculated, assuming 75% of lead in dust and dirt comes from gasoline lead (Table 9, row 26'). With this assumption, gasoline lead would contribute an average of 23 μg (40%) to the daily uptake of lead by an urban child, and 6.2 μg (36%) by an urban adult (rows 28' and 29').

2.3.3 Conclusions. Based on these assumptions, it is estimated that most urban adults derive about 30-35% of their blood lead from gasoline lead additives. The proportion of gasoline lead in children's blood may range from 30 to 40%. Reduction of the lead content of gasoline should significantly lower lead uptake and blood lead levels in the Canadian population.

2.4 Evidence of the Contribution of Gasoline Lead to Lead in Humans

2.4.1 The Isotopic Lead Experiment. The Isotopic Lead Experiment was conducted in Turin and the surrounding area, in the Piedmont region of Italy (39). The lead added to gasoline distributed in the test area came from the Broken Hill mine in Australia. The ratio of the ^{206}Pb : ^{207}Pb isotopes in the Australian lead was 1.04, and was distinct from the lead isotope ratios in nearby ore deposits, soil and vegetation, which ranged from 1.15 to 1.20. From May 1977 until the end of 1979, the ^{206}Pb : ^{207}Pb ratios in blood and environmental samples gave direct evidence on the amount of lead originating from gasoline.

TABLE 9 ESTIMATED CONTRIBUTION OF LEAD IN GASOLINE TO DAILY UPTAKE OF LEAD

	Urban adults		children (1-3 yr)		Rural adults		children (1-3 yr)	
23. total lead uptake from lungs (ug/day) uptake of gasoline lead from lungs (ug/day) ^a	4.3	1.3	0.80	0.24	0.70	0.21		
	3.8	1.1						
24. amount of fallout lead in daily diet (ug/day) contribution of gasoline lead to fallout lead in food (ug/day) ^b	13	7.1	13	7.1				
	11.4	6.3	11.4	6.3				
25. uptake of gasoline lead from food (ug/day)	1.1	3.1	1.1	3.1				
26. lead uptake from dust and dirt in gut (ug/day) percentage contribution of gasoline lead to dust and dirt	1.7	25.5	0.12	1.8				
	50	50	50	50				
27. uptake of gasoline lead from dust and dirt (ug/day)	0.85	12.8	0.06	0.9				
28. total lead uptake from lungs and gut (ug/day) total lead uptake of gasoline lead (ug/day)	17.4	58.1	12.3	33.3				
	5.75	17	1.86	4.2				
29. percentage contribution of gasoline lead to total daily lead uptake	33	29	15	13				
26' percentage contribution of gasoline lead to dust and dirt	75	75	75	75				
27' uptake of gasoline lead from dust and dirt (ug/day)	1.3	19.1	0.09	1.35				
28' total lead uptake of gasoline lead (ug/day)	6.2	23.3	1.9	4.7				
29' percentage contribution of gasoline lead to total daily lead uptake	36	40	15	14				

^a It was assumed that 88% of lead in air originates from leaded gasoline.

^b The contribution of fallout lead to the adult diet was estimated to be 13 ug/day (reference 21); 88% of this was assumed to originate from lead in gasoline.

TABLE 10: ESTIMATED EXPOSURE TO AND UPTAKE OF LEAD AND GASOLINE LEAD UNDER VARIOUS AIR LEAD CONCENTRATIONS(a)

	Urban		2 Times NAPS		High Air Lead		Rural	
	NAPS Air Lead Adults	Children (1-3 yr)	Adults	Children (1-3 yr)	Adults	Children (1-3 yr)	Adults	Children (1-3 yr)
air lead concentration ($\mu\text{g}/\text{m}^3$)	0.27	0.27	0.54	0.54	1.08	1.08	0.10	0.10
lead uptake from lungs ($\mu\text{g}/\text{day}$)	2.2	0.65	4.3	1.3	8.6	2.6	0.80	0.24
lead uptake from food and water ($\mu\text{g}/\text{day}$)	11.4	31.3	11.4	31.3	11.4	31.3	11.4	31.3
lead concentration in dust and dirt ($\mu\text{g}/\text{g}$)	850	850	850	850	2000	2000	60	60
lead uptake from dust and dirt ($\mu\text{g}/\text{day}$)	1.7	25.5	1.7	25.5	4	60	0.12	1.8
(A) total lead uptake from lungs and gut ($\mu\text{g}/\text{day}$)	15.3	57.4	17.4	58.1	24	93.9	12.3	33.3
uptake of gasoline lead from lungs ($\mu\text{g}/\text{day}$)	1.9	0.57	3.8	1.1	7.6	2.3	0.70	0.21
uptake of gasoline lead from food ($\mu\text{g}/\text{day}$)	1.1	3.1	1.1	3.1	1.1	3.1	1.1	3.1
uptake of gasoline lead from dust and dirt ($\mu\text{g}/\text{day}$)	0.85	12.8	0.85	12.8	2	30	0.06	0.9
(B) total uptake of gasoline lead ($\mu\text{g}/\text{day}$)	3.85	16.5	5.75	17	10.7	35.4	1.86	4.2
percentage contribution of gasoline lead to total daily lead uptake (B/A)	25	29	33	29	45	38	15	13

a) See Tables 8 and 9 for details.

The lead content of gasoline was 0.6 g/L during the experiment; atmospheric lead concentrations were 2.0 ug/m³ in Turin, 0.56 ug/m³ within 25 km of Turin, and 0.33 ug/m³ further than 25 km from Turin. About 90% of atmospheric lead in Turin was derived from gasoline lead.

Average blood lead concentrations of 22.5, 26.9 and 29.6 ug/dL were detected in males in Turin, <25 km from Turin, and >25 km from Turin, respectively. Based on the isotopic ratios of lead in the subjects' blood, it was estimated that 24% of blood lead in Turin adults was derived from gasoline. The proportions for the countryside were 12% and 11% for <25 km and >25 km from Turin, respectively.

Although the ²⁰⁶Pb:²⁰⁷Pb isotopic ratios in gasoline and air had stabilized by 1977, the isotopic ratios in blood continued to fall throughout the isotopic exchange period. If equilibrium had not been established, then the contribution of gasoline to blood lead would be higher than that observed.

Gasoline contributed 5.4 ug Pb/dL to the blood lead concentrations of Turin adults and 3.2 ug Pb/dL to the blood lead concentrations of adults in the surrounding area. The mean blood lead level of Toronto residents was found to be 12 ug/dL (28). If leaded gasoline contributes 33% of this amount, then 4 ug/dL blood would be derived from gasoline lead. Indeed, this amount is similar to the level of gasoline lead observed in the blood of rural Piedmont subjects. Thus, the results from the Isotopic Lead Experiment lend support to the calculations described in the previous section and in Tables 8 and 9.

2.4.2 Second National Health and Nutrition Examination Survey (NHANES II). The Second National Health and Nutrition Examination Survey in the United States measured blood lead levels of people aged 6 months to 74 years; the resulting data were analyzed for age, sex, race, family income and location (40). The average blood lead level decreased by 37%, from 14.6 to 9.2 ug/dL, between February 1976 and February 1980. The same trend was noted for each sub-group studied. Changes in lead exposure from the diet or paint could not account for the decline in blood lead levels. The level of lead used in gasoline showed a highly significant correlation with changes in blood lead concentrations. However, it should be noted that the study was not designed to show trends in blood lead concentrations during the study period.

✓ **2.4.3 Umbilical Cord Blood Lead Levels in Boston.** Between April 1979 and April 1981, umbilical cord blood specimens from 11,837 births were analyzed for lead concentration (41). Blood lead levels decreased with time and displayed a definite seasonal pattern. Infants born in summer had higher blood lead levels than those born in winter (7.17 ug/dL versus 5.99 ug/dL, $p < 0.001$). The decrease in lead levels was about 14% per annum. Monthly cord lead levels were significantly correlated with the amounts of gasoline sold in Massachusetts in the same month, and in the two previous months ($p < 0.001$). Lag times of 3 to 12 months gave poorer correlations. No significant monthly fluctuations or trends were found for maternal factors such as tobacco smoking, education, alcohol consumption, or tap water lead levels.

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3.0 GASOLINE DEMAND FORECAST

During the time the proposal to reduce further automotive lead emissions has been under investigation, several gasoline demand forecasts have been available and used for analyses. These forecasts differ; consequently, it is important that an up-to-date and generally acceptable demand forecast be used in the analyses, because it is upon this forecast (and the projected market shares of leaded and lead-free gasolines) that certain key estimates depend. These include estimates of the amount of automotive lead emissions, refinery throughputs and costs, and demand for lead additives.

What follows is a brief discussion of the demand assumptions underlying the selected forecast, projected market shares (or grade split) of leaded and lead-free gasoline, and the automotive lead emissions that would be generated by a maintenance of the regulatory status quo. Further details on these and related topics are available in Appendix C.

3.1 Demand Assumptions

Generally speaking, the variations among past forecasts of gasoline demand have been largely due to the degree to which the downturn in demand, first apparent in 1981 and continuing through to the present, was taken into account. More specifically, however, the variations relate to assumptions regarding the three primary variables common to all the gasoline-demand forecasting models, namely:

- the size and growth of the gasoline-powered vehicle fleet;
- the fuel efficiency of this fleet; and
- the cost of vehicle operation, including capital and maintenance costs, but most importantly, the cost of gasoline to the consumer.

The size of the gasoline-powered vehicle fleet is expected to continue to grow, but only at approximately one-half its rate of 4.8% during the 1970s (42). This decline in growth rate is due to a corresponding decline in growth rate of the car-owning population and an increase in the cost of car ownership and operation.

The fuel economy of the gasoline fleet, which improved only marginally during the period 1968-1978, is expected to improve at a rate of 3.5% per annum through the 1980s (43). In Canada, a voluntary company (manufacturer) average-fuel-consumption (CAFC) objective of 8.6 L/100 km for 1985 has been set for new vehicles (58).

Consumer demand for gasoline is a function of the average annual number of kilometres driven which, in turn, is a function of unitary elasticity with respect to income levels, and negative elasticity with respect to the price of gasoline. Until recently, it was anticipated that the future would be characterized by real increases in gasoline prices in line with the National Energy Program (NEP) outlook. This outlook has been revised due to the declining cost (in real terms) of crude oil on the world market and the possibility of Canada moving to free world market prices. Current expectations are that gasoline prices in Canada will rise in nominal rather than real terms (44).

According to the National Energy Board's December 1982 gasoline demand forecast, the downturn in total gasoline sales, which began in 1981, is expected to continue, but moderate, through the mid-1980s. This downturn will be followed by a stabilization of demand and then an upturn as vehicle fuel economy gains are largely exhausted, income levels improve, and consumers adjust to higher fuel prices (45).

Total gasoline sales, which peaked at slightly over 38 billion litres in 1980, are estimated to be 32.0, 30.7, and 33.5 billion litres in 1987 (possible date of further regulation), 1990, and 2000, respectively.

Figure 3 shows the National Energy Board's December 1982 forecast for total gasoline demand and the projected market shares of leaded and lead-free gasoline. While the absolute numbers deviate marginally, the profile of NEB's forecast correlates well with a recent in-house and as yet unpublished Energy, Mines and Resources forecast (46).

3.2 Leaded and Lead-free Market Shares

Lead-free gasoline's share of total gasoline demand has grown as vehicles with catalytic converters have entered the automobile fleet. It is estimated that 80% of current new car sales are vehicles designed to operate on lead-free fuel. However, car manufacturers are still able to meet current Canadian exhaust emission standards on smaller models without using catalyst technology. They are thus able to offer to consumers vehicles that are able to

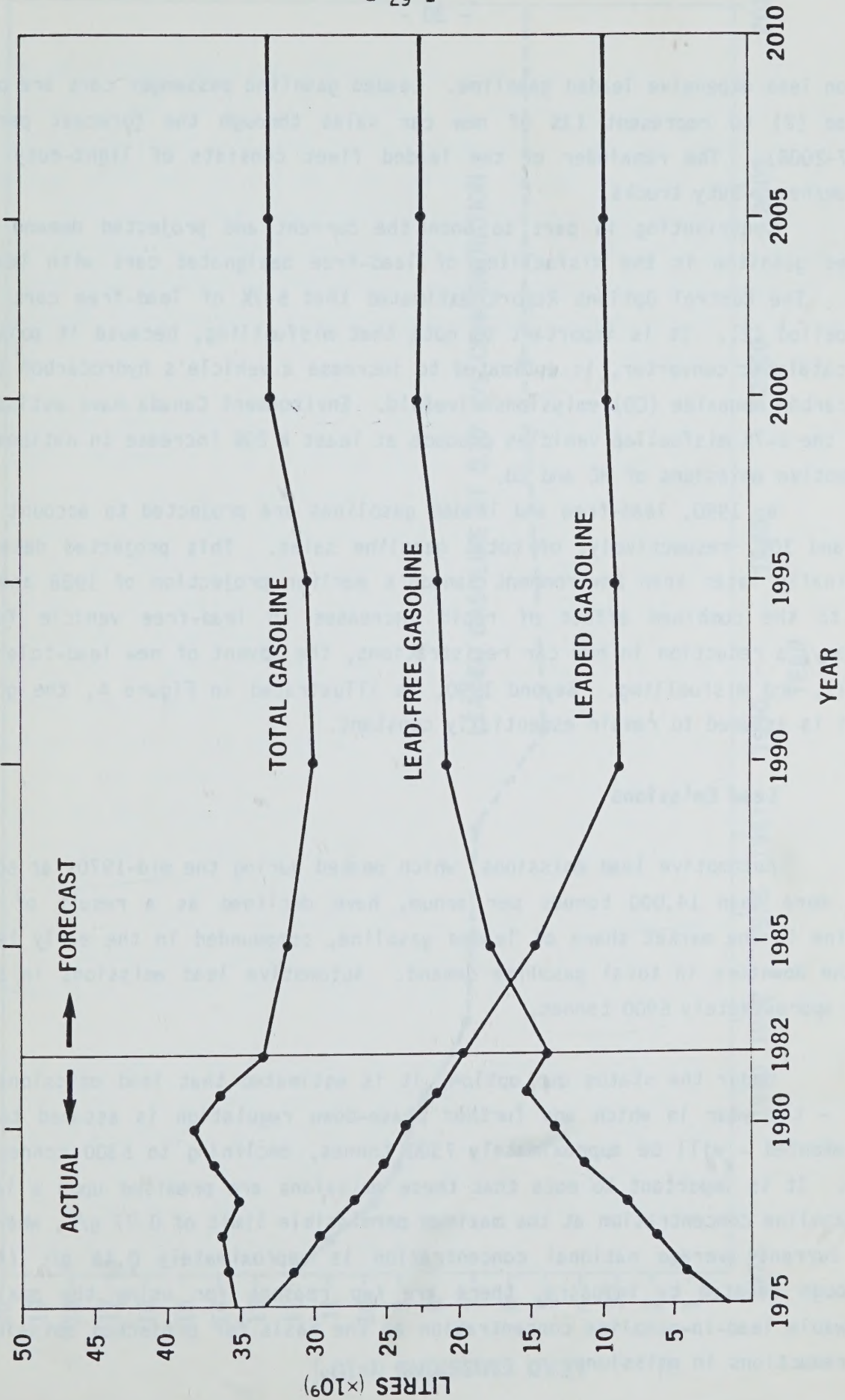


FIGURE 3 GASOLINE SALES IN CANADA, 1975-2010

run on less expensive leaded gasoline. Leaded gasoline passenger cars are projected (2) to represent 13% of new car sales through the forecast period (1987-2006). The remainder of the leaded fleet consists of light-duty and medium/heavy-duty trucks.

Contributing in part to both the current and projected demand for leaded gasoline is the misfuelling of lead-free designated cars with leaded fuel. The Control Options Report estimated that 6-7% of lead-free cars are misfuelled (2). It is important to note that misfuelling, because it poisons the catalytic converter, is estimated to increase a vehicle's hydrocarbon (HC) and carbon monoxide (CO) emissions fivefold. Environment Canada have estimated that the 6-7% misfuelled vehicles produce at least a 20% increase in nationwide automotive emissions of HC and CO.

By 1990, lead-free and leaded gasolines are projected to account for 70% and 30%, respectively, of total gasoline sales. This projected date is marginally later than Environment Canada's earlier projection of 1988 and is due to the combined effect of rapid increases in lead-free vehicle fuel-economy, a reduction in new car registrations, the advent of new lead-tolerant models, and misfuelling. Beyond 1990, as illustrated in Figure 4, the grade split is assumed to remain essentially constant.

3.3 Lead Emissions

Automotive lead emissions, which peaked during the mid-1970s at somewhat more than 14,000 tonnes per annum, have declined as a result of the decline in the market share of leaded gasoline, compounded in the early 1980s by the downturn in total gasoline demand. Automotive lead emissions in 1982 were approximately 6900 tonnes.

Under the status quo option, it is estimated that lead emissions in 1987 - the year in which any further phase-down regulation is assumed to be implemented - will be approximately 7300 tonnes, declining to 5300 tonnes by 1990. It is important to note that these emissions are premised upon a lead-in-gasoline concentration at the maximum permissible limit of 0.77 g/L, whereas the current average national concentration is approximately 0.46 g/L (47). Although debated by industry, there are two reasons for using the maximum allowable lead-in-gasoline concentration as the basis for projected emissions, and reductions in emissions.

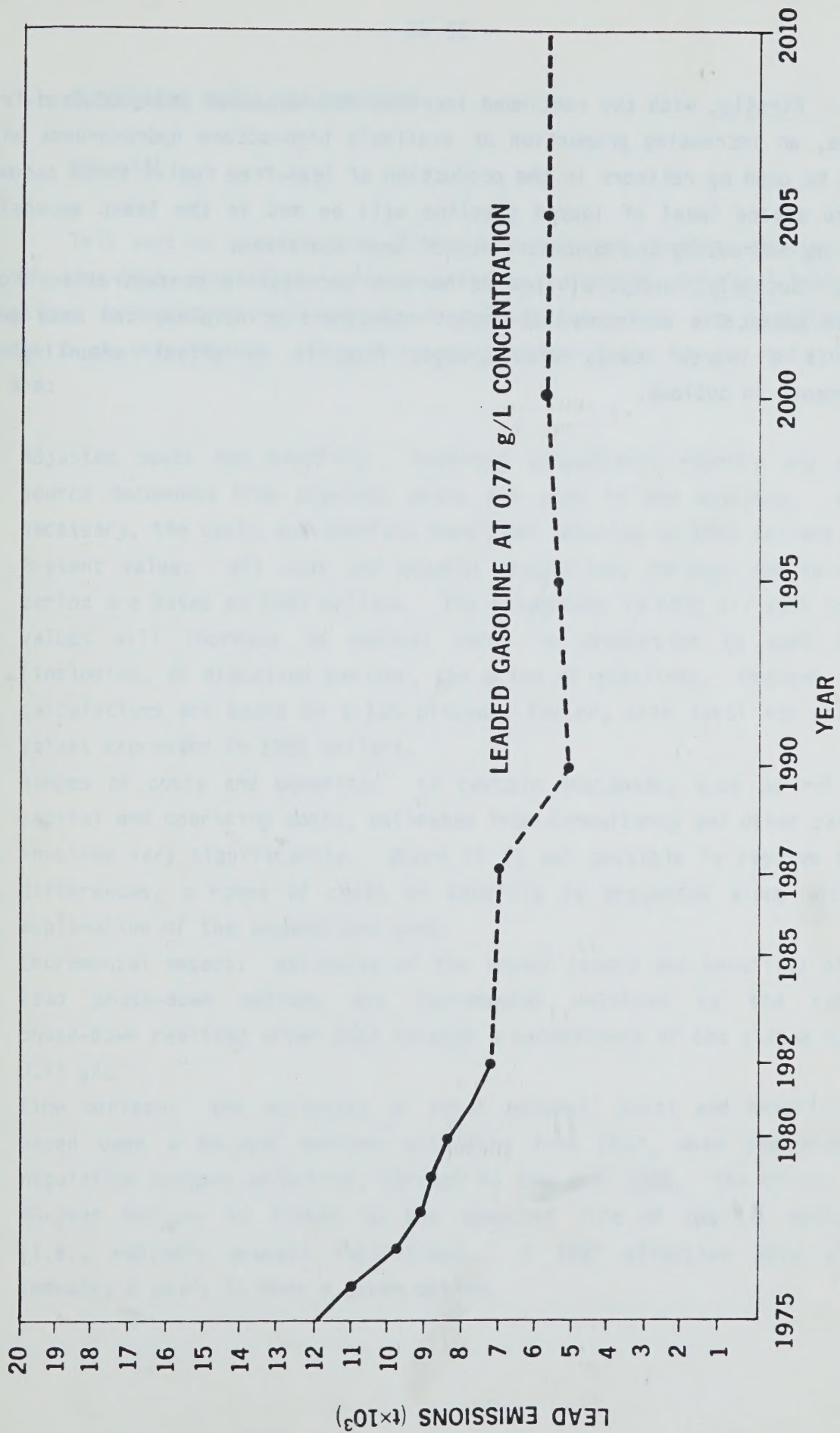


FIGURE 4 VEHICLE LEAD EMISSIONS IN CANADA, 1975-2010

✓ Firstly, with the continued increase in the market share of lead-free gasoline, an increasing proportion of available high-octane hydrocarbons will need to be used by refiners in the production of lead-free fuel. It is assumed that the octane level of leaded gasoline will be met in the least expensive fashion by increasing the concentration of lead additives.

✓ Secondly, analysis based on maximum permissible concentrations conforms to acceptable environmental impact assessment principles; the case presented is a "worst" case, with changes from it in effect amounting to improvements in outlook.

4.0 ALLOCATIVE COSTS AND BENEFITS

4.1 Overview

This section presents the allocative costs and benefits arising from each of the lead phase-down control options. Further details, including assumptions incorporated and methods of calculation used, are contained in Appendix D of this report. The principal considerations of the methodology used are:

- Adjusted costs and benefits: numerous consultants reports and other source documents from previous years are used in the analyses. Where necessary, the costs and benefits have been adjusted to 1983 dollars. ✓
- Present value: all cost and benefit projections through the forecast period are based on 1983 dollars. The assumption is that all such dollar values will increase in nominal terms in proportion to each other (including, as discussed earlier, the price of gasoline). Present value calculations are based on a 10% discount factor, with total net present values expressed in 1983 dollars. ✓
- Ranges of costs and benefits: in certain instances, such as refinery capital and operating costs, estimates from consultants and other parties involved vary significantly. Where it is not possible to resolve these differences, a range of costs or benefits is presented along with an explanation of the assumptions used. ✓
- Incremental impact: estimates of the impact (costs and benefits) of the lead phase-down options are incremental relative to the natural phase-down realized after 1987 through a maintenance of the status quo of 0.77 g/L. ✓
- Time horizon: the estimates of total volumes, costs and benefits are based upon a 20-year horizon extending from 1987, when the proposed regulation becomes effective, through to the year 2006. The choice of a 20-year horizon is linked to the expected life of capital equipment (i.e., refinery process facilities). A 1987 effective date allows industry 3 years to meet a given option. ✓

4.2 Allocative Costs

Allocative costs are expected to be incurred in the following areas as a result of adopting one of the lead phase-down options:

- refinery capital and operating costs, through increased processing requirements;
- closure and decommissioning costs of lead additives manufacturing facilities; and
- consumer costs, for lead traps on new vehicles designed to operate on leaded fuel (Option 6(a)) or for lead traps on new and existing vehicles designed to operate on leaded fuel (Option 6(b)).

4.2.1 Refinery Capital and Operating Costs. For lead-free gasoline production, instead of using lead additives, high-octane hydrocarbons are used to reach a required octane level. As demand for lead-free gasoline increases, so does the requirement for higher severity refining.

MHG International Ltd. (43,48,73) used a process simulator to estimate the additional refinery facilities needed, as well as the associated operating costs, which would result from the following scenarios:

- maximum concentration of lead in leaded gasoline was 0.44 g/L;
- maximum concentration of lead in leaded gasoline was 0.22 g/L;
- lead-free gasoline (regular and premium) which met industry octane specifications; and
- lead-free gasoline (regular and premium) which met the specifications set by the Canadian General Standards Board (CGSB);

For the first two scenarios, MHG indicated that no capital investment would be required, although it was acknowledged that this is a hypothetical conclusion and does not preclude deviations from their model's four-region composite base case. Also, the cost estimates were acknowledged to have a +30% error factor.

For the lead-free gasoline case at higher octane levels (94 RON and 89 (R+M)/2 regular gasoline*), the estimate for capital investment was \$886

* RON is defined as research octane number. (R+M)/2 is the average of RON and MON (motor octane number), otherwise known as the antiknock index (AKI).

million (\$1979) (additional reforming, isomerization, alkylation and desulphurization process facilities) while operating costs were estimated at \$130 million (\$1979). Production of lead-free gasoline at Canadian General Standards Board (CGSB) octane specifications of 92 RON and 87.7 (R+M)/2 generated significantly lower estimates of \$64 and \$34 million (\$1979) for capital and operating costs, respectively, demonstrating the sensitivity of costs to changes in octane levels.

4.2.1.1 Control Options Report/Environment Canada Estimates. The MHG \$64 and \$34 million capital and operating cost estimates were modified by Environment Canada (2) to \$42 and \$32 million (\$1982), respectively, based on the following:

- Octane numbers of 92 RON and 87.7 (R+M)/2 will meet the requirements of Canadian automobiles, based on a survey of automobile manufacturers by Transport Canada (49), and are in line with a reduction in octane levels to 92.5 RON in the U.S.
- MHG estimates were based on 1979 production data. The incremental leaded gasoline volume in 1979 that would be affected by either a reduction in the concentration or total elimination of lead in gasoline at that time was approximately 25.2 billion litres.
- Environment Canada adjusted these cost estimates by first calculating the shortfall in lead-free production capacity (1986 total forecast demand less the petroleum industry's lead-free gasoline production capacity as reported by the Petroleum Association for the Conservation of the Canadian Environment (PACE) (50); then, taking a portion of the MHG cost estimates equivalent to this shortfall (15.5 billion litres) over the 1979 incremental leaded gasoline volume (25.2 billion litres).
- Environment Canada concluded that the refinery energy penalty has been over-emphasized by industry, and assumed that only a portion of the 1.1% increased crude oil requirements would be consumed as process energy (0.5%), with the remainder (0.6%) converted into and sold as other products.

The cost estimates in the Control Options Report are for a once-through, or single, isomerization process. In order to illustrate the capa-

bilities of isomerization units to upgrade total stream octane levels (and therefore increase (R+M)/2 values in gasoline), an additional set of refinery capital and operating cost estimates has been calculated by Environment Canada for a recycle isomerization process. It is important to note that the estimated sales-weighted averages of the (R+M)/2 octane values produced by the single and recycle isomerization cases are 87.7 and 88.9, respectively.

4.2.1.2 Industry Estimates. The refinery capital and operating costs used in this analysis to reflect industry estimates are those obtained from industry and submitted by PACE (51). These are premised upon, among other considerations, AKIs of 91.8 for premium and 88.7 for regular gasolines (current market sales-weighted averages).

In the absence of documentation and supporting data, it was further assumed for the purposes of this SEIA that PACE estimates are possibly overstated inasmuch as they reflect not only the incremental volume over and above 70% lead-free under the status quo option, but the additional production required to reach 100% lead-free volume from the current lead-free sales of 42% (or an increase of nearly 60%) (52). The PACE cost estimates were therefore halved to show a 30% additional lead-free capacity demand rather than a 60% additional demand.

A summary of the range of cost estimates for each option that is generated by the foregoing is shown in Table 11. Further information on relevant material is contained in Appendix D. This includes a report on alternative octane enhancers that could be used by refiners to increase the octane number of the gasoline pool.

4.2.2 Lead Additives Manufacturers. The decline in demand for leaded gasoline will result in a corresponding decline in demand for lead additives manufactured by Du Pont Canada Ltd. and Ethyl Canada Ltd. In 1982, these two plants were operating at 53% of their combined capacity; with forecast leaded gasoline sales (and at 0.77 g Pb/L), demand for lead additives should be the same in 1987 under the status quo control option, falling to 39% of capacity by 1990.

Although both plants are assumed to remain in operation under Option 1 (status quo), it is suggested that, with a reduction to 0.29 g/L, one

TABLE 11 SUMMARY OF REFINERY CAPITAL AND OPERATING COST ESTIMATES (\$ MILLIONS) (\$1983)

Option	Environment Canada Single Isomerization (CGS8 Octane Specs.)		Environment Canada Recycle Isomerization		PACE Maximum		PACE Adjusted	
	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating ^a	Capital	Annual Operating ^a
1 0.77 g/L	--	--	--	--	--	--	--	--
2 0.29 g/L	20	15	--	--	240	40	120	20
3 0.15 g/L	30	25	--	--	825	120	415	60
4 Lead-free	46	34	150	40	1,100	180	550	90
5 Lead-free, Except for 0.15 g/L Heavy Trucks ^b	46	34	150	40	1,100	180	550	90

^a Industry estimates of operating costs have been recalculated to delete capital charges, insurance and taxes equivalent to 25% of capital cost shown.

^b Assumed to be roughly equivalent to all lead-free production.

plant would close (MHG, in their study (53), indicated that this would possibly be Du Pont's). Cleaning and dismantling are estimated to incur decommissioning costs of \$3 million (\$2.1 million (\$1983) assuming closure in 1987).

One plant alone would presumably handle market demand under Options 2 and 3 (0.15 g/L). Both plants would close under Option 4 (all lead-free) and Option 5 (0.15 g/L for heavy trucks; minor requirements for lead additives would be met by imports). The total decommissioning costs, including dedicated railway tank cars and refinery lead additives facilities, would reach approximately \$9.6 million (\$6.6 million (\$1983)).

4.2.3 Lead Traps. The consumer would incur direct costs under Options 6 (a) and (b), either through the installation of lead traps on new vehicles (differential cost of lead trap vs conventional muffler) or the retrofit of lead traps on existing, leaded-gasoline-designated vehicles (full retail cost for lead trap as a replacement). In both instances, lead traps are assumed to be made of galvanized steel, whereas a study conducted by Pilorusso Research Associates (54) based the comparison on stainless steel lead traps. Appendix D discusses the arguments in favour of a comparison based on a galvanized lead-trap vs a galvanized conventional muffler system.

The unit costs used to calculate the impact on the consumer are at best very approximate because lead traps have not been produced commercially (Appendix D). The differential cost of lead traps on new vehicles is estimated to be \$1.08 billion over the years 1987-2006 (\$280 million (\$1983)) while the retrofit, assumed to take place during 1985-86, would cost \$476 million (\$375 million (\$1983)), for a total program cost of \$1.56 billion (\$660 million (\$1983)).

Aside from the speculative nature of the unit costs used, no costs are included for a compliance program or for the collection and treatment/disposal of discarded lead traps. The feasibility of recycling the lead in traps has been investigated in the U.S.; no data are available for Canada (55). These and other considerations are discussed in Appendix D.

4.3 Allocative Benefits

In addition to the reduction of lead emissions achieved under Options 2-6, it is estimated that fuel economy and maintenance savings would be obtained through the conversion to lead-free gasoline under Options 4 and 5.

4.3.1 Reduction of Automotive Lead Emissions. The cumulative atmospheric lead emissions that will be produced by gasoline-powered vehicles under each of the control options during the years 1987-2006 and the reduction in emissions, relative to the status quo, are summarized in Table 12. The annual automotive lead emissions for each of the control options are shown in Figure 5.

TABLE 12 ESTIMATED AUTOMOTIVE LEAD EMISSIONS AND REDUCTION RELATIVE TO STATUS QUO (CUMULATIVE, 1987-2006)

Option	Emissions (t x 10 ³)	Reduction (t x 10 ³)
1. Status Quo	115,100	--
2. 0.29 g/L	43,300	71,800
3. 0.15 g/L	22,100	93,000
4. Lead-free	0	115,100
5. 0.15 g/L for heavy trucks only	3,600	111,500
6. Lead Trap		
a) New Vehicles	57,400	60,700
b) New and Retrofit	38,200	76,900

4.3.2 Fuel Economy Savings. A car fueled with lead-free gasoline and equipped with a catalytic converter to meet emission standards is believed, in some instances, to be more fuel efficient than an identical car which is fueled with leaded gasoline and is not so equipped to meet emission standards. However, quantification of these fuel savings has been the subject of debate (refer to Appendix D). For the purposes of this study, it is estimated that a savings of 2.8% is possible for new lead-free designated cars entering the market and displacing lead-tolerant cars (under the status quo, lead-tolerant cars would otherwise account for 13% of the new car market over the forecast period) (2). These fuel savings, over the period 1987-2006, are estimated to be \$530 million (\$127 million (\$1983)).

4.3.3 Maintenance Savings. Vehicles that operate on lead-free rather than leaded fuel reportedly realize maintenance savings equivalent to \$1/1000 km as a result of improvements in spark plug and muffler system life (42). No savings are realized unless the gasoline is lead-free. Although these savings theoretically apply to both new and existing vehicles, for the

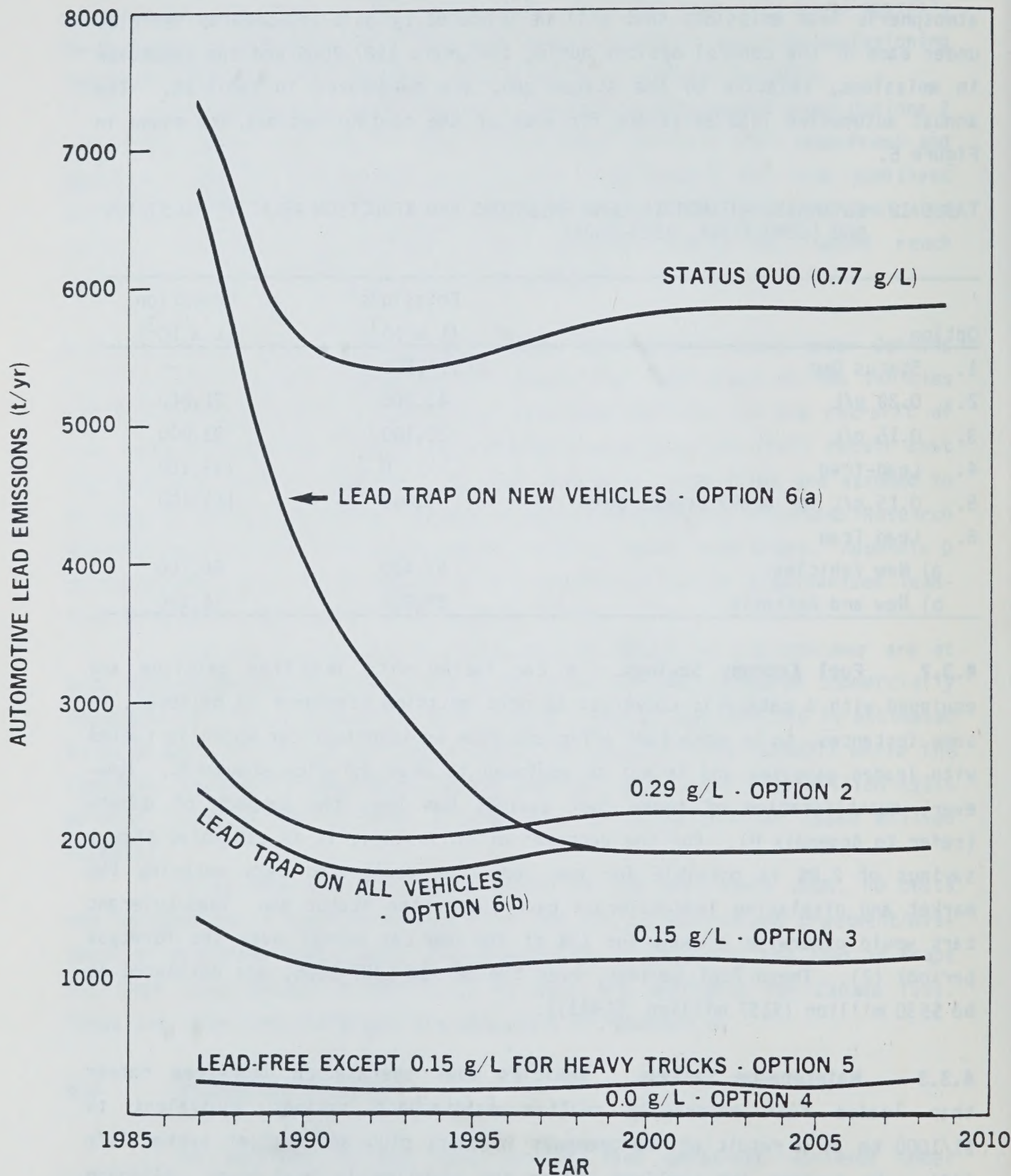


FIGURE 5 FORECAST OF AUTOMOTIVE LEAD EMISSIONS FOR VARIOUS CONTROL OPTIONS

purpose of this analysis they have been estimated based only on new vehicle sales after 1987. Passenger cars, light-duty and medium/heavy-duty trucks have been included. Estimated savings (1987-2006) under Option 4 are \$1.0 billion (\$240 million (\$1983)). With heavy-duty trucks burning gasoline at a lead concentration of 0.15 g/L, the savings under Option 5 would be \$815 million (\$207 million (\$1983)).

4.4 Incremental Allocative Costs and Benefits

It should be recalled that the costs and benefits realized as a result of Options 2-6 are incremental to what would otherwise materialize under the status quo, or base case, over the years 1987-2006. Tables 13 through 18 summarize the allocative benefits and costs discussed. Also illustrated are the net benefits or costs realized by each option, and the cost-effectiveness of that option (\$1983) in reducing automotive lead emissions.

TABLE 13 SUMMARY OF ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR
LEAD PHASE-DOWN IN GASOLINE - OPTION 1 (Status Quo) (1987-2006)

Lead in Gasoline	0.77 g/L
<u>Incremental Gasoline^a (L x 10⁹)</u>	
Lead-free Gasoline	
Leaded Gasoline	199.3
Lead Emissions, (t)	115,100
Emissions Reduction, (t)	0
<u>Cost (\$ x 10⁶)</u>	
Refinery Investment	0
Refinery Operating Cost	0
Lead Traps	0
Lead Antiknock Manufacturers	0
Total	0
Present Value (\$1983)	0
<u>Benefit (\$ x 10⁶)</u>	
Fuel Savings	0
Maintenance Savings	0
Total	0
Present Value (\$1983)	0
<u>Net Benefit (Cost) (\$ x 10⁶)</u>	
Total	0
Present Value (\$1983)	0
<u>Cost Effectiveness (\$/t)</u> <u>(Present Value (\$1983))</u>	
Net Benefit (Cost) of Lead Emissions Reduction	0
<u>Cents Per Litre of Incremental Gasoline</u> <u>(Present Value (\$1983))</u>	
Cost	0
Benefit	0
Net Benefit or (Cost)	0
<u>Cents Per Litre of Total</u> <u>Gasoline Demand (Present Value (\$1983))</u>	
Cost	0
Benefit	0
Net Benefit (Cost)	0

^a Incremental Gasoline - means the volume of leaded gasoline that would be used under the Status Quo from 1987 to 2006. This incremental volume does not include lead-free gasoline predicted to be used under the Status Quo, Option 1.

TABLE 14 SUMMARY OF ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR LEAD PHASE-DOWN IN GASOLINE - OPTION 2 (1987-2006)

Lead in Gasoline	0.29 g/L		
	Environment Canada Minimum ^b	PACE Maximum ^c	PACE Adjusted ^d
<u>Incremental Gasoline^a (L x 10⁹)</u>			
Lead-free Gasoline	-	-	-
Leaded Gasoline	193.3	193.3	193.3
Lead Emissions (t)	43,300	43,300	43,300
Emissions Reduction (t)	71,800	71,800	71,800
<u>Cost (\$ x 10⁶)</u>			
Refinery Investment	20	240	120
Refinery Operating Cost	300	800	400
Lead Traps	0	0	0
Antiknock Manufacturers	3	3	3
Total	323	1043	523
Present Value (\$1983)	114	452	227
<u>Benefit (\$ x 10⁶)</u>			
Fuel Savings	0	0	0
Maintenance Savings	0	0	0
Total	0	0	0
Present Value (\$1983)	0	0	0
<u>Net Benefit (Cost) (\$ x 10⁶)</u>			
Total	(323)	(1043)	(523)
Present Value (\$1983)	(114)	(452)	(227)
<u>Cost Effectiveness (\$/t)</u> <u>(Present Value (\$1983))</u>			
Net Benefit (Cost) of Lead Emissions Reduction	(1590)	(6300)	(3160)
<u>Cents Per Litre of Incremental Gasoline</u> <u>(Present Value (\$1983))</u>			
Cost	0.05	0.23	0.12
Benefit	-	-	-
Net Benefit or (Cost)	(0.05)	(0.23)	(0.12)
<u>Cents Per Litre of Total</u> <u>Gasoline Demand (Present Value (\$1983))</u>			
Cost	N/A	N/A	N/A
Benefit	N/A	N/A	N/A
Net Benefit (Cost)	N/A	N/A	N/A

^a Incremental Gasoline - means the volume of leaded gasoline that would be used from 1987 to 2006. This incremental volume does not include lead-free gasoline predicted to be used under the Status Quo, Option 1.

^b Environment Canada Minimum Refinery Costs - Environment Canada, "Control Options Report", February, 1983; CGSB octane levels; costs inflated to 1983.

^c PACE Maximum Refinery Costs - PACE submission containing industry estimates of costs based on maintaining current market octane levels.

^d PACE Adjusted - for incremental volumes beyond natural phase-down to status quo, 70% lead-free.

TABLE 15 SUMMARY OF ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR LEAD PHASE-DOWN IN GASOLINE - OPTION 3 (1987-2006)

Lead in Gasoline	0.15 g/L		
	Environment Canada Minimum ^b	PACE Maximum ^c	PACE Adjusted ^d
<u>Incremental Gasoline^a (L x 10⁹)</u>			
Lead-free Gasoline	-	-	-
Leaded Gasoline	193.3	193.3	193.3
Lead Emissions, (t)	22,100	22,100	22,100
Emissions Reduction, (t)	93,000	93,000	93,000
<u>Cost (\$ x 10⁶)</u>			
Refinery Investment	30	825	415
Refinery Operating Cost	500	2,400	1,200
Lead Traps	0	0	0
Antiknock Manufacturers	3	3	3
Total	533	3,228	1,618
Present Value (\$1983)	187	1,438	721
<u>Benefit (\$ x 10⁶)</u>			
Fuel Savings	0	0	0
Maintenance Savings	0	0	0
Total	0	0	0
Present Value (\$1983)	0	0	0
<u>Net Benefit (Cost) (\$ x 10⁶)</u>			
Total	(533)	(3,228)	(1,618)
Present Value (\$1983)	(187)	(1,438)	(721)
<u>Cost Effectiveness (\$/t)</u> <u>(Present Value (\$1983))</u>			
Net Benefit (Cost) of Lead Emissions Reduction	(2,010)	(15,460)	(7,750)
<u>Cents Per Litre of Incremental Gasoline</u> <u>(Present Value (\$1983))</u>			
Cost	0.10	0.74	0.37
Benefit	-	-	-
Net Benefit or (Cost)	(0.10)	(0.74)	(0.37)
<u>Cents Per Litre of Total</u> <u>Gasoline Demand (Present Value (\$1983))</u>			
Cost	N/A	N/A	N/A
Benefit	N/A	N/A	N/A
Net Benefit (Cost)	N/A	N/A	N/A

^a Incremental Gasoline - means the volume of leaded gasoline that would be used from 1987 to 2006. This incremental volume does not include lead-free gasoline predicted to be used under the Status Quo, Option 1.

^b Environment Canada Minimum Refinery Costs - Environment Canada, "Control Options Report", February, 1983; CGSB octane levels; costs inflated to 1983.

^c PACE Maximum Refinery Costs - PACE submission containing industry estimates of costs based on maintaining current market octane levels.

^d PACE Adjusted - for incremental volumes beyond natural phase-down to status quo, 70% lead-free.

TABLE 16 SUMMARY OF ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR LEAD PHASE-DOWN IN GASOLINE - OPTION 4 (1987-2006)

Lead in Gasoline	0.0 g/L - All Vehicles			
	Environment Canada Minimum ^b	Environment Canada Recycle ^c	PACE Maximum ^d	PACE Adjusted ^e
<u>Incremental Gasoline^a (L x 10⁹)</u>				
Lead-free Gasoline	193.3	193.3	193.3	193.3
Leaded Gasoline	-	-	-	-
Lead Emissions (t)	0	0	0	0
Emissions Reduction (t)	115,100	115,100	115,100	115,000
<u>Cost (\$ x 10⁶)</u>				
Refinery Investment	46	150	1,100	550
Refinery Operating Cost	680	800	3,600	1,800
Lead Traps	0	0	0	0
Antiknock Manufacturers	10	10	10	10
Total	736	960	4,710	2,360
Present Value (\$1983)	262	384	2,048	1,027
<u>Benefit (\$ x 10⁶)</u>				
Fuel Savings	530	530	530	530
Maintenance Savings	1,000	1,000	1,000	1,000
Total	1,530	1,530	1,530	1,530
Present Value (\$1983)	367	367	367	367
<u>Net Benefit (Cost) (\$ x 10⁶)</u>				
Total	794	570	(3,180)	(830)
Present Value (\$1983)	105	(17)	(1,681)	(660)
<u>Cost Effectiveness (\$/t)</u> (Present Value (\$1983))				
Net Benefit (Cost) of Lead Emissions Reduction	910	(150)	(14,605)	(5,735)
<u>Cents Per Litre of Incremental Gasoline</u> (Present Value (\$1983))				
Cost	0.14	0.20	1.06	0.53
Benefit	0.19	0.19	0.19	0.19
Net Benefit or (Cost)	0.05	(0.01)	(0.87)	(0.34)
<u>Cents Per Litre of Total</u> <u>Gasoline Demand (Present Value (\$1983))</u>				
Cost	0.04	0.06	0.32	0.16
Benefit	0.06	0.06	0.06	0.06
Net Benefit or (Cost)	0.02	0.00	(0.26)	(0.10)

^a Incremental Gasoline - means the volume of leaded gasoline that would be used from 1987 to 2006. This incremental volume does not include lead-free gasoline predicted to be used under the Status Quo, Option 1.

^b Environment Canada Minimum Refinery Costs - Environment Canada, "Control Options Report", February, 1983; CGSB octane levels; costs inflated to 1983.

^c Environment Canada Recycle - Isomerization Recycle, Environment Canada Estimates.

^d PACE Maximum - PACE submission containing industry estimates of costs based on maintaining current market octane levels.

^e PACE Adjusted - for incremental volumes beyond natural phase-down to status quo, 70% lead-free.

TABLE 17

SUMMARY OF CONTROL ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR
LEAD PHASE-DOWN IN GASOLINE - OPTION 5 (1987-2006)

Lead in Gasoline	0.0 g/L - All Vehicles, Except 0.15 g/L for Heavy Trucks			
	Environment Canada Minimum ^b	Environment Canada Recycle ^c	PACE Maximum ^d	PACE Adjusted ^e
<u>Incremental Gasoline^a (L x 10⁹)</u>				
Lead-free Gasoline	174.6	174.9	174.9	174.9
Leaded Gasoline	18.4	18.4	18.4	18.4
Lead Emissions, (t)	3,600	3,600	3,600	3,600
Emissions Reduction, (t)	111,500	111,500	111,500	111,500
<u>Cost (\$ x 10⁶)</u>				
Refinery Investment	46	150	1,100	550
Refinery Operating Cost	680	800	3,600	1,800
Lead Traps	0	0	0	0
Antiknock Manufacturers	10	10	10	10
Total	736	960	4,710	2,360
Present Value (\$1983)	262	384	2,048	1,027
<u>Benefit (\$ x 10⁶)</u>				
Fuel Savings	530	530	530	530
Maintenance Savings	815	815	815	815
Total	1,345	1,345	1,345	1,345
Present Value (\$1983)	334	334	334	334
<u>Net Benefit (Cost) (\$ x 10⁶)</u>				
Total	609	385	(3,365)	(1,015)
Present Value (\$1983)	72	(50)	(1,714)	(693)
<u>Cost Effectiveness (\$/t)</u> (Present Value (\$1983))				
Net Benefit (Cost) of Lead Emissions Reduction	645	(450)	(15,370)	(6,215)
<u>Cents Per Litre of Incremental Gasoline</u> (Present Value (\$1983))				
Cost	0.14	0.20	1.06	0.53
Benefit	0.17	0.17	0.17	0.17
Net Benefit or (Cost)	0.03	(0.03)	(0.89)	(0.36)
<u>Cents Per Litre of Total Gasoline Demand</u> (Present Value (\$1983))				
Cost	0.04	0.06	0.32	0.16
Benefit	0.05	0.05	0.05	0.05
Net Benefit or (Cost)	0.01	(0.01)	(0.27)	(0.11)

^a Incremental Gasoline - means the volume of leaded gasoline that would be used from 1987 to 2006. This incremental volume does not include lead-free gasoline predicted to be used under the Status Quo, Option 1.

^b Environment Canada Minimum Refinery Costs - Environment Canada, "Control Options Report", February, 1983; CGSB octane levels; costs inflated to 1983.

^c Environment Canada Recycle - Isomerization Recycle, Environment Canada Estimates.

^d PACE Maximum - PACE submission containing industry estimates of costs based on maintaining current market octane levels.

^e PACE Adjusted - for incremental volumes beyond natural phase-down to status quo, 70% lead-free.

TABLE 18 SUMMARY OF ALLOCATIVE BENEFITS AND COSTS OF CONTROL OPTIONS FOR LEAD PHASE-DOWN IN GASOLINE - OPTION 6 (LEAD TRAP) (1987-2006)

Lead in Gasoline	0.77 g/L	
	New Vehicles ^b	New & Retrofit ^c
<u>Incremental Gasoline^a</u> (L x 10 ⁹)		
Lead-free Gasoline		
Leaded Gasoline	193.3	193.3
Lead Emissions (t)	57,400	38,200
Emissions Reduction (t)	57,700	76,900
<u>Cost (\$ x 10⁶)</u>		
Refinery Investment	0	0
Refinery Operating Cost	0	0
Lead Traps	1,080	1,560
Antiknock Manufacturers	0	0
Total	1,080	1,560
Present Value (\$1983)	280	660
<u>Benefit (\$ x 10⁶)</u>		
Fuel Savings	0	0
Maintenance Savings	0	0
Total	0	0
Present Value (\$1983)	0	0
<u>Net Benefit (Cost) (\$ x 10⁶)</u>		
Total	(1,080)	(1,560)
Present Value (\$1983)	(280)	(660)
<u>Cost Effectiveness (\$/t)</u> (Present Value (\$1983))		
Net Benefit (Cost) of Lead Emissions Reduction	(4,850)	(8,580)
<u>Cents Per Litre of Incremental Gasoline^a</u> (Present Value (\$1983))		
Cost	0.14	0.34
Benefit	-	-
Net Benefit or (Cost)	(0.14)	(0.34)
<u>Cents Per Litre of Total Gasoline Demand</u> (Present Value (\$1983))		
Cost	N/A	N/A
Benefit	N/A	N/A
Net Benefit or (Cost)	N/A	N/A

^a Incremental Gasoline - means the volume of leaded gasoline that would be used from 1987 to 2006. This incremental volume does not include lead-free gasoline, predicted to be used under the Status Quo, Option 1.

^b 6(a) New Vehicles - lead-trap installed on new vehicle sales (leaded-gasoline designated).

^c 6(b) New and Retrofit - same as 6(a) plus retrofit of lead trap on existing leaded-gasoline designated vehicles.

5.0 NON-ALLOCATIVE EFFECTS

The following section presents an assessment of the non-allocative effects of the lead phase-down control options upon the following three industrial sectors:

- automotive parts aftermarket;
- lead additives manufacturers; and
- lead industry.

Areas of concern are the impacts of non-allocative effects upon market structure, competition, output and employment within these sectors. The effect of the control options upon distribution of income and balance of payments is also discussed.

5.1 Automotive Parts Aftermarket

The percentage of the forecast vehicle fleet which requires lead-free gasoline serves as a baseline for measuring the impact on manufacturers and installers of automotive replacement parts. A study conducted by Hickling-Partners Inc. (42) indicated that the lead-free option would accelerate market shifts which are currently underway. The aftermarket remained essentially unchanged during the 1974-1979 period. However, the sale of replacement parts is expected to decline over the next decade as a result of catalytic control technology and the continuing efforts of North American manufacturers to downsize cars and use engines with fewer cylinders.

As a result of this shift to lighter and more efficient vehicles, the parts manufacturing industry, composed mainly of large, diversified companies, is in a state of rapid technological change. However, only 11.5% of the total market for repair parts (i.e., spark plugs and exhaust system mufflers) would potentially be affected by the lead-free options. The consultant suggests that any adverse impact could be alleviated by growth in other product lines of the conglomerate manufacturing companies concerned.

The aftermarket's distribution system is comprised of manufacturers (both vehicle assemblers and independent producers), jobber-wholesalers and retailers. The diversity of activity and product lines within each distribution channel makes most companies relatively insensitive to technological and

regulatory changes or to consumer trends (e.g., emergence of "do-it-yourself" repairs) in the replacement parts market.

The Department of Industry, Trade and Commerce estimated that the value of manufactured goods in the Canadian parts aftermarket in 1979 was \$1.2 billion (42). Of this total, spark plugs and exhaust systems accounted for minor portions; the former about 4%, or \$50 million, the latter roughly 7.5%, or \$90 million.

Of the \$50 million market for spark plugs in 1979, Champion Spark Plug Company of Canada held nearly 66%, A.C. Spark Division of General Motors Corporation, 20-25%, and Autolite Division of Bendix Corporation, 10-15%. The \$90 million Canadian market for exhaust components is supplied largely by four companies with products manufactured in Canada. Walker Exhausts (accounting for 50%), which franchises Speedy Muffler, and International Parts (Canada) Ltd. (accounting for 25%) with its Midas International Division, together command 75% of market. A.P. Parts of Canada and Thrush Inc., the sole exporter, account for the remainder. While some 30% of the domestic market for exhaust components in 1979 was supplied by imports, Canada was a net exporter of these products due to the shipments of specialty exhaust systems to the U.S. by Thrush Inc.

The consultant estimated that, in the 6 years after promulgation of a lead-free regulation, 24.3 million fewer spark plugs cumulatively would be sold (a reduction of 9.5%). Similarly, sales of conventional muffler systems would decline by 1.35 million, or 14.8%.

At the retail sales and services level for automotive replacement parts, the impact of the regulation is expected to be felt unevenly over the diverse outlets, with the most sensitive channel being service stations which depend on the tune-up of older vehicles for a significant part of their total revenue, and to a limited extent on exhaust system repairs. The least affected would be the authorized dealers of new North American vehicles.

The exhaust system service market is vertically integrated with franchised dealers (e.g., Speedy and Midas) installing the products of Canadian manufacturers. As the speciality muffler shops account for some 60% of the total repair trade, they would be the most affected by a lead-free regulation. Mass retailers, such as Canadian Tire and Sears, appear to be the next most sensitive.

Clearly, revenue and profits in the replacement parts industry would be reduced with the implementation of the lead-free option. However, because of the lack of reliable data in the area of parts distribution, a quantitative evaluation is not possible. Likewise, inasmuch as the companies are wholly-owned subsidiaries of American corporations, no discrete financial information is available regarding the manufacturers of spark plugs and mufflers.

The estimated cumulative reductions in sales of spark plugs (9.5%) and muffler systems (14.8%) indicated above should be viewed in light of the percentage of the total aftermarket accounted for by each of these items (4% and 7.5%, respectively).

5.2 Lead Additives Manufacturers

The allocative costs resulting from the closure and decommissioning of one or both of the lead additives manufacturing plants (Ethyl and Du Pont) are described in Section 4.2.2.

Both plants are assumed to remain in operation under Options 1 and 6. Option 2 (0.29 g/L) would probably result in the closure of one plant; should the smaller plant (Du Pont) close, an estimated 158 jobs would be lost (53). Option 3 (0.15 g/L) may result in some manpower reductions at the remaining plant. Elimination of lead in gasoline would result in the closure of both plants, with a total loss of 337 jobs. Under Option 5, it is assumed that the minor demand for additives to produce leaded gasoline with 0.15 g/L for heavy-duty trucks would be met by imports.

The International Lead and Zinc Research Organization (ILZRO) have stated that with a 0.15 g/L regulation, both plants would close and additives would have to be imported at a cost of approximately \$25 million/year (56). Furthermore, ILZRO claims that closure of both plants would result in the loss of 419 jobs (including associated sales force) in contrast to the 337 estimated by MHG, and that the "ripple" effect would eliminate another 1260 jobs.

5.3 Lead Industry

Canada ranks third in the Western World in terms of primary lead (mine) production, and eighth in terms of consumption of both primary and secondary (recycled) lead. According to a report by Energy, Mines and Resources, exports are a key factor in this industry, accounting for more than 66% (225,000 tonnes) of the 1981 mine production of 332,000 tonnes (1).

The major end-use of lead is in the manufacture of lead-acid batteries, representing 66% of primary lead consumption in Canada in 1980, followed by chemical compounds at 19%. Other end-uses of lead include solders, ammunition, sheathing and plumbing. By far the largest requirement in the chemical compound category is for lead additives. In 1980 these represented 80% of chemical end-use and 15% of Canadian primary refined lead consumption. Due to the requirement for high-purity metal, the lead used in lead additives comes almost exclusively from primary lead.

Reduced demand for lead will occur as a result of the natural phase-down of leaded gasoline under Option 1. Choice of any one of the other options would accelerate this decline (except for Option 6 where lead demand will be the same as for Option 1). Table 19 shows lead use in gasoline additives for each option, as well as the percentage this represents of primary refined lead consumption in Canada.

5.3.1 Implications of Control Options. In June 1982, Energy, Mines and Resources (EMR) carried out a study of the implications for the Canadian lead industry of further reducing the lead content of gasoline. This study, which was not made available at the time the Control Options Report was prepared, is included as Appendix B of this SEIA.

The conclusions and implications, as identified by EMR, may be summarized as follows:

- in Canada, as in the Western World generally, mine production of lead is expected to show little growth over the next decade, with declining consumption of lead additives and other end-use products being offset by growth in battery production and a few newer uses;
- alternative markets will not exist in Canada for lead sales lost as the result of any reduction in exports;
- the competitive cost advantage enjoyed by Canadian producers in domestic markets (through lower transportation costs, tariffs and other factors) will not apply internationally when producers attempt to find export markets for lost domestic sales;
- annual domestic consumption for lead-in-gasoline additives has fallen by 10,000 tonnes between 1973 (peak demand) and 1982. Under Option 1, and with natural phase-down of leaded gasoline, it is estimated that an additional 4300 tonnes per year of lead sales would be lost by 1990;

TABLE 19 LEAD USE IN GASOLINE ADDITIVES (Regulatory Date - 1987)

	Pre-Regulation		Post-Regulation		
	1980	1985	1990	1995	2000
Leaded Gasoline Forecast (L x 10 ⁹)	24.2	14.8	9.2	9.3	10.1
Lead Use (t x 10 ³) and % of Canadian Consumption of Primary Refined Lead Production ^a Option					
1. 0.77 g/L ^b	10.9 (15%)	11.4 (15%)	7.1 (9.5%)	7.2 (9.7%)	7.8 (10.5%)
2. 0.29 g/L	10.9 (15%)	11.4 (15%)	2.7 (3.6%)	2.7 (3.6%)	2.9 (3.9%)
3. 0.15 g/L	10.9 (15%)	11.4 (15%)	1.4 (1.9%)	1.4 (1.9%)	1.5 (2.0%)
4. Lead-free ^c	10.9 (15%)	11.4 (15%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)

^a 74,600 tonnes in 1980.

^b Same for lead trap Option 6.

^c Same for Option 5.

- the lead producing industry is also concerned about the potential domino effect of an accelerated lead-in-gasoline phase-down by Canada upon the regulations of other countries;
- nonetheless, Canadian lead producers expect to find alternative export markets for sales lost in the domestic lead additive markets. Further regulatory action will result in additional costs for alternative export sales. Revenue losses resulting from natural phase-down under Option 1 are estimated to be \$3.6 million through the 1980s. A lead-free gasoline option would result in incremental revenue losses of approximately \$2 million. This assumes alternative export markets do in fact materialize and that the price effects of this market shift are negligible;
- detailed assessment of the effect of revenue losses upon mine and smelter profitability, production life, employment, tax revenues, etc., is only possible through financial analysis of each lead producer. This would be complicated and probably inconclusive because, for the mines in question, lead is produced in conjunction with other metals;
- reduced revenues could shorten the lives of some mines, make some potential new mines uneconomic, and discourage investment in plant modernization and expansion; and
- provided producers find alternative export markets, the impact on employment is not expected to be very large.

5.3.2 Comments on Implications. The consideration of possible spin-off effects of more stringent Canadian lead-in-gasoline regulations upon comparable regulations in other Western countries, and the effect that these could have upon the important Canadian export markets, would be hypothetical and inappropriate. The control options and their effects (whether reduced emissions and health benefits, or reduced consumption/production) should be judged in the Canadian context.

More importantly, demand for lead in gasoline additives is already forecast to decline from 15% of Canadian primary lead consumption to under 10% through the 1990s. This forecast is based on the use of a maximum allowable lead-in-gasoline concentration of 0.77 g/L; if the actual concentration is less, the demand will be correspondingly lower.

In 1990, the incremental decline in consumption of primary refined lead used in gasoline additives is expected to be approximately 5.9%, 7.6% and

9.5% under the 0.29 g/L, 0.15 g/L and lead-free options, respectively, when compared to Option 1 (Table 19).

5.4 Overview of Impact Upon Employment

Employment impacts have been identified in the petroleum refining and lead additives industries. Based on available information, the incremental impact upon employment within the automotive parts aftermarket and primary lead industries is estimated to be negligible even with complete elimination of leaded gasoline.

The effects of Option 6 (lead trap) upon employment were not investigated in the study. Although strictly speculative, it may be assumed that the manufacture of lead traps would counterbalance the decline in conventional muffler systems manufacture. Lead trap disposal and recycling could possibly be assimilated by the existing secondary lead (recycling) industry.

5.4.1 Petroleum Refining. MHG International Ltd. estimated that approximately 250 additional refinery personnel (process operators and laboratory technicians) would be required if only lead-free gasoline at CGSB specifications were produced (48). Reduction, but not elimination, of lead-in-gasoline (Options 2 and 3) would presumably require some additional process personnel, although the numbers were not estimated.

MHG International Ltd. also estimated that total lead-free production at higher octane levels would generate 900-1000 more jobs (process operators, utility operators, maintenance engineers, laboratory technicians, clerical staff and process engineers) for the additional reformer and isomerization process units needed (43). Increased manpower requirements were not, however, identified within the PACE estimates of the petroleum industry's capital and operating costs.

Construction of process facilities necessitated by each of Options 2 to 5 would also create employment for engineering, procurement and construction personnel during the pre-regulatory period. For the lead-free option at higher octane levels, MHG indicated that about 4000 person-years would be required (43). Corresponding requirements for Options 2 and 3 are not available; nevertheless, based on the comparatively small capital cost estimates for these cases, it is assumed that construction manpower requirements would likewise be small. It should be noted that the labour costs of these construction

personnel are included in the capital cost estimates discussed earlier; ongoing wages and salaries for additional process personnel are included in the overall operating cost estimates.

5.4.2 Lead Additives Manufacturers. Minor loss of jobs would probably occur as both Du Pont's and Ethyl's plants adjust to declining demand under natural phase-down (53). Options 2 and 3, as noted earlier, would result in the closure of one plant, possibly Du Pont's, and therefore the loss of 158 jobs. It is estimated that Options 4 and 5 would result in the closure of both plants and a corresponding loss of 337 jobs (process operators, maintenance operators, laboratory technicians, administrators, and sales and marketing personnel). Alternatively, ILZRO has estimated the loss of 419 jobs with a lead-free option, and a "ripple" effect eliminating another 1260 jobs (56).

5.4.3 Net Effect upon Employment. Due to the nature of the available information on employment losses and gains, it is difficult to estimate with any certainty the net effect upon employment of the control options under consideration. For Options 2 and 3, the loss of jobs in the lead additives industry would seem to outweigh increased employment in the petroleum refineries.

With total lead-free production, job losses through the closure of both additives plants (337 estimated by MHG, 419 by ILZRO) would outweigh job creation (250) at the refineries under the "minimum" case (lead-free at CGSB specifications, or once-through isomerization).

On the other hand, lead-free production at higher octane levels and with increased process units would generate requirements for an additional 900-1000 personnel. However, these estimates by MHG were based on 1979 volumes and need to be adjusted for incremental volumes beyond 1987 in the same fashion as was used earlier when treating refinery capital and operating costs. Recognizing that such an adjustment is at best a rough approximation, it is estimated that 500 additional refinery process personnel could be required. This would offset the job losses realized by closure of the lead additives plants.

There is some degree of similarity between certain of the jobs affected in the additives plants and the additional jobs required by the refineries. In theory, the dislocations realized in the former may perhaps be partially offset by job creation in the latter. However, an analysis of this possibility has not been carried out.

5.5 Balance of Payments

Generally speaking, as lead-in-gasoline concentrations are progressively reduced, the refiner must increase the crude oil feed to produce the high-octane hydrocarbons necessary to maintain the octane number of of leaded gasoline and to provide energy for the processing units. At a time when Canada is aiming for crude oil self-sufficiency by 1990, any such additional crude requirement may to some extent be regarded as offshore or imported crude, thereby affecting the balance of payments.

To quantify the effect, however, is difficult. The refinery cost estimates used in this SEIA incorporate non-uniform assumptions and are presented in varying degrees of detail, making it difficult to evaluate refinery crude oil penalties.

The cost of increased crude requirements for refinery crude oil penalties is included in the refinery operating cost estimates, but these are net operating cost estimates which include several cost factors, some of which increase with a reduction of lead-in-gasoline concentrations while others decrease. However, the cost of the total crude is higher than shown in the net operating costs because only the net crude requirements for the refinery energy penalty are included.

Determining the level of the refinery energy penalty and the impact upon the balance of payments is further complicated by other considerations. Environment Canada claim that only a portion of the incremental crude oil demand is consumed as processing energy, while the remainder is converted to other products (2). The processing energy requirement is claimed to be further offset by the energy that would otherwise be required to produce lead additives and by fuel savings realized by vehicles using lead-free gasoline. In conclusion, Environment Canada judges that the issue of a refinery energy penalty has been overemphasized (2).

On the other hand, PACE estimates that an additional 14-16 million barrels of crude oil would be required annually by the petroleum industry to compensate for loss of yield (51). At a cost of \$30/bbl., this represents \$420-480 million.

However, there is no indication of whether, and to what extent, this estimate takes into account the sale or alternative use of other petroleum products derived from this crude, the decrease in energy requirements for lead additives production, or the projected automobile fuel savings. Furthermore, as previously discussed, it is not known whether the PACE operating cost is a

true reflection of incremental volumes and production requirements beyond the natural phase-down realized under Option 1.

5.6 Distribution of Income

A rough indication of the effect upon the distribution of income of Canadians may be obtained by expressing the net benefits and costs of each control option as a cents-per-litre equivalent of projected gasoline sales over the period 1987-2006. These estimates, contained in Tables 13-18, are summarized in Table 20.

The equivalent cents-per-litre impact of each option has been calculated based upon the incremental gasoline sold over the years 1987-2006 and the total gasoline demand over the same period. The incremental gasoline for each option equals the volume of gasoline that would be sold as leaded gasoline under Option 1. For Options 2, 3 and 6, this is leaded gasoline at the various lead additive concentrations. Under Option 4, the incremental gasoline is lead-free gasoline, and under Option 5, both lead-free (for all vehicles except heavy trucks) and leaded (0.15 g/L lead in gasoline for heavy trucks only) gasolines are included as incremental gasoline.

Options 2, 3 and 6 give rise to increased costs (without offsetting monetary benefits) as the result of producing leaded gasoline at reduced lead additive concentrations (Options 2 and 3) or the cost of installing and retrofitting lead traps (Option 6). In these instances, the costs incurred are the result of continuing to produce and sell leaded gasoline; one may perhaps assume that the costs could be assigned (in theory, at least) to the leaded gasoline segment of the vehicle population.

However, with total lead-free gasoline, the incremental costs incurred over and above the status quo (70% lead-free) cannot logically be assigned to a particular segment of the vehicle population. Rather, the net benefit or cost should be assigned to total gasoline sales because whatever pricing adjustments are made would presumably be made across the board and would therefore affect all purchasers of gasoline.

It is emphasized that such a cents-per-litre equivalent is at best a rough indication of, or proxy for, the effect upon distribution of income. The estimates must be used with caution, keeping in mind:

TABLE 20 DISTRIBUTION OF INCOME - CENTS-PER-LITRE EQUIVALENT (1987-2006)

	Incremental Gasoline	Total Gasoline
Gasoline Sales Forecast (Cumulative, 1987-2006) Litres x 10 ⁹	193.3	643.2
Cents-per-litre Benefit or (cost)		
Option 1. 0.77 g/L	0	N/A
2. 0.29 g/L		
-E.C. Minimum	(0.05)	N/A
-PACE Maximum	(0.23)	N/A
-PACE Adjusted	(0.12)	N/A
3. 0.15 g/L		
-E.C. Minimum	(0.10)	N/A
-PACE Maximum	(0.74)	N/A
-PACE Adjusted	(0.37)	N/A
4. Lead-free		
-E.C. Minimum	0.05	0.02
-E.C. Recycle	(0.01)	0.00
-PACE Maximum	(0.87)	(0.26)
-PACE Adjusted	(0.34)	(0.10)
5. Lead-free/Except 0.15 g/L for Heavy Trucks		
-E.C. Minimum	0.03	0.01
-E.C. Recycle	(0.03)	(0.01)
-PACE Maximum	(0.89)	(0.27)
-PACE Adjusted	(0.36)	(0.11)
6. Lead Trap		
6(a) New Vehicles	(0.14)	N/A
6(b) New and Retrofit	(0.34)	N/A

a Incremental Gasoline - the volume of leaded gasoline that would be used 1987-2006 under Option 1. Sold as leaded under Options 1, 2, 3 and 6, as lead-free under Option 4, and as both lead-free (174.9 billion litres) and leaded (18.4 billion litres for heavy trucks) under Option 5.

- that they assume pricing behaviour by gasoline marketers that would directly reflect projected costs. It is impractical to speculate whether the costs incurred as a result of continuing sales of leaded gasoline would be included in the market price of that portion of gasoline sales, or whether the price of both leaded and lead-free gasoline would be adjusted to absorb the increased costs;
- the relationship of benefits and costs to the refinery process. Whereas increased refinery processing costs may be reflected in the pump price of gasoline, projected fuel economy savings would not affect refinery processing costs and would not, therefore, alter the pump price. These are direct savings to the consumer resulting from reduced gasoline consumption;
- that fuel savings result from the use of lead-free gasoline. It is these leaded-gasoline-vehicle owners that would derive the benefit, whereas an equivalent cents-per-litre impact based on total gasoline demand infers that all vehicle owners would be affected;
- the cost of decommissioning the lead additive plants and the benefits derived from maintenance savings do not affect refinery process costs. Therefore, as with fuel savings, they cannot be viewed as having a direct impact on the pump price of gasoline;
- deletion of non-refinery process benefits (fuel economy and maintenance) and costs (additive plant decommissioning) would result in a substantially larger cents-per-litre impact than is indicated under Options 4 and 5 (Table 20).

Under Options 2 and 3, owners of leaded-gasoline vehicles would be affected if there were a specific change in the price of leaded gasoline to reflect increased production costs. Option 6 also shows the leaded-gasoline vehicle owners as being affected. Under Option 6(a), lead traps would be installed on new leaded-gasoline vehicles; the cost would be incorporated in the sale price of the vehicle. Under Option 6(b), lead traps would also be required on existing (pre-1987) leaded-gasoline vehicles; the cost to the consumer would be the retail price of this retrofit. Option 6(a) would have an impact on purchasers of new automobiles while Option 6(b), at least initially, would also have an impact on owners of older, leaded-gasoline vehicles. Any

change in the price of lead-free gasoline under Options 4 and 5 would affect all car owners. Fuel economy and maintenance savings would benefit consumers who switch from leaded-gasoline vehicles to new, lead-free gasoline vehicles.

Not reflected in the estimated cents-per-litre impact under Options 4 and 5 is the consideration that consumers who change from leaded to lead-free designated vehicles would presumably pay a higher price per litre for lead-free vs leaded gasoline. Whether or not this would equal the current price differential between leaded and lead-free gasoline is not known.

An exception to the above are heavy truck operators who, under Option 5, would still have access to leaded gasoline. No fuel economy or maintenance savings would be achieved by this group. It is not possible to estimate whether, and to what extent, the price of this leaded gasoline would change.

6.0 CONCLUSIONS

Based on an assessment of the health effects of lead and an analysis of data on Canadian blood lead levels, Health and Welfare Canada have concluded that a reduction of automotive lead emissions is desirable.

Because the benefit derived from a reduction of automotive lead emissions is a reduction of the lead burden of Canadians, the net benefits or costs of the control options cannot be expressed in terms of a benefit-cost ratio. Rather, the relative measure of each option is based upon the cost-effectiveness of that option expressed in terms of the net benefit or cost per tonne of lead emissions reduced. This cost-effectiveness measure is used for the control options considered in this SEIA and the results are given in Table 21.

The emissions reductions achieved with each of Options 2-6 are reductions from the total automotive lead emissions that would otherwise occur with a maintenance of the status quo (Option 1). Under Option 1, it is estimated that the natural phase-down of the leaded-gasoline fleet will result in annual lead emissions of 5300 tonnes in 1990 and 5800 tonnes in 2000 (although leaded-gasoline consumption is forecast to stabilize at 30% of total gasoline sales, the increase in emissions in year 2000 compared to 1990 is due to a forecast increase in total gasoline demand). Actual automotive lead emissions in 1982 were approximately 6900 tonnes. Estimated emissions under Option 1 assume that the maximum allowable lead-in-gasoline concentration of 0.77 g/L will be used. However, if lower concentrations of lead are used then there would be correspondingly lower annual emissions.

In addition to their cost-effectiveness per tonne of lead emissions reduced, the control options may also be assessed in terms of how quickly the annual lead emissions would decline. Figure 5 illustrates the estimated lead emissions up to 2006 that would result from the adoption of each control option in 1987 (the proposed regulatory date). It is apparent that, with the exception of Option 6(a) (lead traps on new leaded-gasoline vehicles only), all control options realize immediate reductions in lead emissions.

Lead emissions under Option 6(a) decline gradually as new leaded-gasoline vehicles equipped with lead traps enter the vehicle fleet. Towards the late 1990s, emissions under Option 6(a) would match those under Option 6(b) as all leaded vehicles pre-dating 1987 are phased out.

TABLE 21 COST-EFFECTIVENESS OF LEAD PHASE-DOWN CONTROL OPTIONS, 1987-2006
(Present Value, \$1983)

Option	Emission Reduction ^a (t x 10 ³)	Net Benefit or (Cost) ^b (\$ x 10 ⁶)	Benefit or (Cost) Per Tonne Reduction of Lead Emissions (\$/t)
1. Status Quo 0.77 g/L	-	-	-
2. 0.29 g/L			
-E.C. Minimum ^c	71.8	(114)	(1,590)
-PACE Maximum ^d	71.8	(452)	(6,300)
-PACE Adjusted ^e	71.8	(227)	(3,160)
3. 0.15 g/L			
-E.C. Minimum	93.0	(187)	(2,010)
-PACE Maximum	93.0	(1,438)	(15,460)
-PACE Adjusted	93.0	(721)	(7,750)
4. Lead-free			
-E.C. Minimum	115.1	105	910
-E.C. Recycle	115.1	(17)	(150)
-PACE Maximum	115.1	(1,681)	(14,605)
-PACE Adjusted	115.1	(660)	(5,735)
5. Lead-free Except 0.15 g/L for Heavy Trucks			
-E.C. Minimum	111.5	72	645
-E.C. Recycle	111.5	(50)	(450)
-PACE Maximum	111.5	(1,714)	(15,370)
-PACE Adjusted	111.5	(693)	(6,215)
6. Lead Trap			
6(a) New Vehicles	60.7	(280)	(4,850)
6(b) New & Retrofit	76.9	(660)	(8,580)

^a Total automotive lead emissions from 1987 to 2006, relative to reductions achieved under the status quo (Option 1).

^b Cost includes capital construction costs from 1984 to 1986.

^c Environment Canada cost estimate.

^d Industry cost estimate.

^e Industry cost estimate adjusted to reflect existing lead-free refinery capacity and only incremental increase in refinery capacity after 1987.

The costs given for both the lead-trap options (6(a) and 6(b)) are of necessity estimates because there is no experience with commercial production of lead traps. Furthermore, the costs used do not include the costs of a compliance program or for recycling discarded lead traps.

Likewise, the fuel economy and maintenance savings projected under Options 4 and 5 (lead-free) are most favourable estimates. Any modifications of the assumptions and calculations could result in a reduction of savings and, therefore, an increase in the cost per tonne of lead emissions reduced.

The non-allocative effects of the control options discussed in detail previously are summarized below:

- Implementation of the lead-free options will affect the spark plug and muffler system segments of the automotive parts aftermarket. These segments account for 4% and 7.5%, respectively, of the total parts aftermarket. Six years after the implementation of a lead-free option, a decline in demand for spark plugs of approximately 9.5%, and for muffler systems of 14.8%, is forecast.
- In 1980, lead additives accounted for 15% of Canadian primary refined lead consumption. Under Option 1, this percentage will decline to 9.5% by 1990. Under Options 2, 3, 4 and 5, consumption of primary refined lead will be 3.6%, 1.9% , 0% and 0%, respectively, by 1990.
- Both Canadian lead additives manufacturers are expected to stay in business under Options 1 and 6; one plant would probably close under Options 2 and 3, while both are assumed to close under lead-free Options 4 and 5.
- The net effect upon employment of Options 2 and 3 would be a loss of jobs due to the closure of one lead additives plant. A lead-free option would result in the loss of 337 jobs due to closure of both plants. In contrast, approximately 250 additional and on-going refinery jobs would be created under the minimum lead-free case (once-through isomerization), while 900-1000 additional personnel would be required under the maximum lead-free scenario. Under a lead-free option at maximum capital costs, requirements for refinery construction personnel could be as high as 4000 man-years.

- The cents-per-litre impact of the net benefits or costs for each control option ranges from a benefit (i.e., savings) of 0.02 ¢/L (Option 4 at minimum refinery costs, and spread over total gasoline demand) to a cost increase of 0.74 ¢/L (Option 3 at maximum refinery costs, and spread over incremental leaded gasoline only). These estimates, however, are rough indicators of the impact upon distribution of income and are not to be construed as changes in the retail price of gasoline.

LIST OF ENGINEERING CONSULTANT STUDIES

1. Incremental Costs to the Refining Industry Associated with the Reduction in Lead Antiknock Grade in Gasoline (IMG International Ltd.)
2. Incremental Costs to the Refining Industry Associated with the Removal of Lead Antiknock Additives in Gasoline, Based on Product Specifications Issued by the Canadian Government, Specifications Based 1985 International Ltd.)
3. Assessment of Energy Requirements for Gasoline Production in Canadian Refineries (IMG International Ltd.)
4. Recalculation of Energy Penalty Values for Various Schemes of Gasoline Production (IMG International Ltd.)
5. A Study of the Incremental Capital and Operating Costs to the Lead Antiknock Manufacturers Associated with the Reduction in Lead Antiknock Grade in Gasoline (IMG International Ltd.)

APPENDIX A

LIST OF ENGINEERING CONSULTANT STUDIES

6. Assessment of Energy Requirements for the Production of Gasoline in Canadian Refineries (IMG International Ltd.)
7. Assessment of the Economic Impact of the Automotive Partnership Initiative of Program Gasoline Lead Content Regulations (Wickling-Partners Inc.)
8. Investigation of the Effect of Fuel Type and Compression Ratio on Fuel Consumption (Wickling-Partners Inc.)
9. Automotive Fuel Consumption Analysis - U.S. vs Canada (Wickling-Partners Inc.)
10. Comparison of Fuel Consumption between Vehicles Designed for 100% and Defueled Fuels (Dew's Engineering Ltd.)
11. Gasoline Fuel Savings in Cars as a Result of using Lead-free Gasoline in Cars (Dew's Engineering Ltd.)
12. A Summary Report by Environment Canada of the Highway Research Association Study on "Structural Damage from Gasoline"
13. An Analysis of the Estimated Costs and Benefits of Lead Free Relative to Conventional Fuel/Filter Systems (Holland Research Associates Ltd.)
14. Effects of Reductions in the Level of Ethyl Additives in Gasoline Incremental Distribution Costs (Pace, Parvika and Partners)
15. Impact Gasoline Excise Tax (Lavett and Economics Inc.)
16. Assessment of Potential Reduction in Leaded Gasoline Fuel in Refinery Construction Costs (IMG International Ltd.)
17. Human Exposure to Environmental Lead (Health and Welfare Canada, Bureau of Chemical Control)

LIST OF ENGINEERING CONSULTING STUDIES

1. Incremental Costs to the Refining Industry Associated with the Reduction in Lead Antiknock Usage in Gasoline (MHG International Ltd.)
2. Incremental Costs to the Refining Industry Associated with the Removal of Lead Antiknock Additive in Gasoline, Based on Product Specifications Issued by the Canadian Government Specifications Board (MHG International Ltd.)
3. Assessment of Three Scenarios for Gasoline Production in Canadian Regions (MHG International)
4. Recalculation of Energy Penalty Values for Various Scenarios of Gasoline Production (MHG International Ltd.)
5. A Study of the Incremental Capital and Operating Costs to the Lead Antiknock Manufacturers Associated with the Reduction in Lead Antiknock Usage in Gasoline (MHG International Ltd.)
6. Assessment of Energy Penalty for the Petroleum Refineries for the Production of Lead-free Motor Gasoline (MHG International Ltd.)
7. Assessment of the Economic Impact on the Automotive Parts/Service Industry of Proposed Gasoline Lead Content Regulations (Hickling-Partners Inc.)
8. Investigation of the Effect of Fuel Type and Compression Ratio on Fuel Consumption (Hickling-Partners Inc.)
9. Automotive Fuel Consumption Analysis - U.S. vs Canada (1980-83) (an update; Hickling-Partners Inc.)
10. Comparison of Fuel Consumption between Vehicles Equipped for Leaded and Unleaded Fuels (Davis Engineering Ltd.)
11. Gasoline Fuel Savings in Canada as a Result of Using Lead-free Gasoline in Cars (Davis Engineering Ltd.)
12. A Summary Prepared by Environment Canada of the Pilorusso Research Associates' Study on "Forecast Demand for Gasoline"
13. An Analysis of the Estimated Costs and Benefits of Lead Traps Relative to Conventional Muffler Systems (Pilorusso Research Associates Ltd.)
14. Effects of Reductions in the Level of Lead Additives in Gasoline: Incremental Distribution Costs (Peat, Marwick and Partners)
15. Leaded Gasoline Excise Tax (Lavalin and Econosult Inc.)
16. Assessment of Partial Reduction in Leaded Gasoline Pool on Refinery Construction Costs (MHG International Ltd.)
17. Human Exposure to Environmental Lead (Health and Welfare Canada, Bureau of Chemical Hazards)

IMPLICATIONS OF REDUCED LEAD-IN-GASOLINE LIMITS FOR THE CANADIAN LEAD INDUSTRY (Mining Policy Sector, Energy, Mines and Resources Canada)

Regulations established in 1974 limit the lead content of gasoline in Canada. Environment Canada is studying the possibility of reducing this limit, or perhaps of phasing out lead use in gasoline entirely. While lead used for this purpose (in Canada and abroad) constitutes an important market for Canadian-produced lead, there is no evidence that Environment Canada has undertaken any detailed analysis of the impact of such a decision on the Canadian lead industry. Indeed, in its February 1982 Status Report on the Leaded Gasoline Phase-down Project, Environment Canada concludes only that removal of lead from gasoline would release the metal for other uses.

This paper evaluates the implications of reduced lead consumption in gasoline on the Canadian industry, as a contribution to a broader evaluation of the proposed phase-down being undertaken in the Department of Energy, Mines and Resources. Because lead markets and pricing are essentially international in character, the paper begins with a brief review of world^a consumption and supply, including use of lead in antiknock gasoline additives. It then reviews the Canadian lead industry in this world context, evaluates expected trends in the use of lead in gasoline over the next decade, and concludes by assessing potential implications for the Canadian lead industry of any accelerated phase-down in lead in gasoline.

As this paper is being prepared, current markets for lead and jointly produced metals are severely depressed. Lead, zinc and silver prices, for example, have fallen by about 42%, 29% and 86%, respectively, from their highs of a year or so ago. Most Canadian producers are experiencing serious financial losses and many temporary mine and smelter/refinery closures have been implemented or announced because of depressed metal demand. The year 1982 appears likely to be the financially most disastrous year since at least the 1930s for the Canadian lead producing industry. It is hoped that metal demand and prices will improve over the next year or so, but lead, zinc and silver all face uncertain longer-term price futures. Among metals co-produced with lead, zinc (like lead) has suffered from lost markets in some of its most important uses, while silver markets are vulnerable to speculative overhangs, U.S. stockpile disposals, and dishoarding. Accordingly, any decision on a lead-in-gasoline phase-down seems particularly inopportune under current industry conditions.

The Western World Lead Industry

Lead is an internationally traded commodity and prices are determined by the interaction of world-wide supply and demand. Western World lead consumption has grown by an average of just under 2% annually since 1971, peaking at over 4.3 million tonnes in 1979 before falling to 3.8 million tonnes in 1981. The leading end use, and one of the few uses that grew during the

^a The analysis actually is based on the Western World. Centrally planned countries as a group are close to self-sufficient in lead but, in recent years, have had net imports from the West of a few tens of thousands of tonnes annually.

period, is lead-acid batteries. Batteries currently account for just over half of total consumption. Most other uses, such as gasoline additives, pigments, solders, ammunition, cable sheathing and plumbing (ranked in order of importance as lead users), are declining.

Future lead consumption trends will continue to depend on the battery market, principally in the traditional automotive and industrial uses although growth in the automotive market will be dampened by the trend to lighter, maintenance-free batteries. Battery prospects for electric utility load levelling and private electric vehicles under the most optimistic circumstances will have a very limited impact on overall lead consumption at least during the 1980s and probably the 1990s as well. The outlook for lead in most other non-battery uses is bleak, despite some promise in newer uses such as nuclear shielding and sound attenuation; total consumption for uses other than batteries is expected to continue to decline.

Recent studies of Western World lead consumption by SRI International and Chase Econometrics^a forecast that annual growth will continue at about 2% or a little higher during the 1980s but will decline to 1.5% during the 1990s. Thus, total consumption would be about 5 million tonnes in 1990 and 5.7 million tonnes in the year 2000. These forecasts assume only a modest decline in the use of lead in gasoline additives. Much of this growth will occur in developing countries.

Lead demand is met from two sources: new mine production and recycling. Secondary metal contributes a higher proportion of total lead supply than for any other major metal, and this proportion is growing. During the 1970s, Western World lead mine production remained stagnant at 2½ million tonnes per year; and all growth in consumption was met by increased recycling.

Lead generally occurs in ore bodies, mixed with other metallic minerals. In recent years, less than 30% of newly mined lead in the Western World (and almost none in Canada) has been produced from ores containing predominantly lead.^b About 8% is produced as a more or less minor byproduct of zinc, copper and other ores. In 1976, about 57% of silver, 61% of zinc and 13% of copper production was from mixed ores containing lead. As mines have no significant flexibility in modifying the shares of lead and other metals in their production, and as lead is more often than not regarded as a joint product, lead supply and prices are strongly influenced by the demand for other metals, notably zinc and silver. Demand for lead has, on the other hand, less impact on supply of zinc.

Unmined lead resources are considered ample to meet requirements for the foreseeable future, within the expected price range. Present Western World capacity is 2.8 million tonnes per year and this could be augmented significantly through future mine development provided metal prices rebound from their current very low levels.

^a SRI International, Metallic Minerals Program - 1981, Vol. 6, World Lead, (February, 1982); and Chase Econometrics Associates, Inc., Lead Forecast, (February 1982).

^b Source: International Lead and Zinc Study Group, "Joint Production of Lead and Zinc", (November, 1978).

Refined lead is produced either at plants that treat predominantly lead concentrates (although most also process some scrap), or at secondary plants. Western World capacity in these two categories is about 4 million and 3 million tonnes per year, respectively. Therefore, existing metal capacity is adequate to meet expected requirements beyond the end of this century. Operating rates at secondary plants depend on the availability of scrap feed, which in turn depends on price levels. These plants therefore tend to act as a market "flywheel" to balance supply and demand.

Forecasts of future lead supply (SRI and Chase) suggest that nearly all growth in Western World lead consumption will continue to be met from secondary sources. Consequently, lead mine production is likely to experience only limited growth.

Recent trends in Western World lead consumption (primary plus secondary) and mine production (i.e., primary only) are shown in Table 1.

TABLE 1 WESTERN WORLD LEAD CONSUMPTION AND PRODUCTION, 1970-81 (t x 10³)
(From: International lead and Zinc Study Group)

	Year			
Consumption	1970	1974	1978	1981
Americas of which:	1360	1709	1771	1426
U.S.	1134	1374	1404	1051
Canada	85	100	101	107
EEC (Ten)	1077	1126	1303	1222
Other W. Europe	267	325	332	357
Africa/M. East	44	66	83	108
Japan	211	217	352	378
Other Asia/Oceania	159	222	283	312
Total Consumption	3118	3665	4124	3803
<u>Mine Production</u>				
U.S.	540	616	542	452
Australia	440	360	387	363
Canada	357	328	366	332
Peru	164	166	183	188
Mexico	173	218	164	149
South Africa	71	55	38	149
Others	824	797	859	817
Total	2569	2540	2539	2450

Western World Use of Lead for Antiknock Additives

Most developed countries established limits on the lead content of gasoline during the 1970s; total Western World consumption of lead for gasoline additives peaked about 1973. Major producers of lead additives are the U.S.A. and the U.K., and much of their production is exported. Trends in lead used for additives in these and other countries for which data are available are as follows (from SRI and International Lead and Zinc Study Group, $t \times 10^3$):

	<u>1970</u>	<u>1973</u>	<u>1974</u>	<u>1978</u>	<u>1981^e</u>
U.S.	253	249	228	178	116
U.K.	40	50	56	61	58
Italy	..	..	10	12	16
France	..	..	14	15	15
Canada	17	19	18	12	10
W. Germany	..	..	9	9	10
Others	55	52	22	23	23
Total	365	370e	357	310	248

.. Means data not available separately, included in "others";

e Figures for 1981 are estimates.

Consumption peaked in the U.S. in 1972 and in Canada in 1973, but has continued to grow in other listed countries. SRI forecasts that overall consumption for lead antiknock will continue to fall during the 1980s, but much less rapidly than during the 1970s, with the total falling to 220,000 tonnes by 1990.

Lead in Canada

Canada ranks about eighth among Western World lead consuming countries but ranks third in production, after the United States and Australia. Consumption of lead (primary plus secondary) in Canada showed some growth in the early 1970s but has since levelled off, as follows ($t \times 10^3$, 1981 data not yet available):

	1970	1972	1974	1976	1978	1980
<u>Primary Lead</u>						
Batteries	19.7	30.4	27.4	27.1	47.2	49.6
Chemicals	20.0	20.3	20.9	20.6	15.8	14.1
(of which antiknock)	(16.7)	(16.6)	(18.1)	(14.8)	(12.4)	(10.9)
Other Uses	25.0	13.1	6.9	4.5	8.7	11.3
<u>Secondary Lead</u>	30.7	49.1	34.5	45.5	29.1	32.2
<u>Total Consumption</u>	85.4	112.9	99.7	107.7	100.8	106.8

As in other countries, batteries are the predominant end use for lead in Canada (about half of secondary lead is also used for this purpose), with chemical uses, mainly antiknock additives, ranking second. Most other uses have fallen significantly since the early 1970s. Consumption is likely to grow only slowly in the future, assuming the domestic battery industry remains competitive. Some battery plants have closed recently, however, and a continuation of this trend would result in declining total lead use in Canada.

Canadian mine production was 332,000 tonnes in 1981, which was off about 10% from the peak levels of the late 1970s. Lead is produced in some two dozen mines located in most provinces and territories, but major production is in New Brunswick, British Columbia, the Yukon and the Northwest Territories. Three-quarters of production comes from four large mines: Cominco's Kimberley, B.C., and Pine Point, N.W.T., mines; Cyprus Anvil's Faro, Y.T., mine; and the Brunswick Mining and Smelting mine (controlled by Noranda Mines Ltd.) near Belledune, N.B. All are also large zinc producers. Cominco operates mines producing lead in Spain, the U.S., Greenland and Australia, and opened another significant lead-zinc mine (the Polaris) in the Arctic Islands in 1982, making the company the world's largest mined lead producer. It also has a 40% interest in a Japanese lead smelter and recently announced the discovery in Alaska of one of the world's largest lead-zinc deposits. Mines that produce lead in Canada also account for about 85% of both zinc and silver mine production. While the relative contribution of lead to overall revenues varies widely among mines, 1 tonne of lead is produced on average for each 3.1 tonnes of zinc (the proportion of lead is much higher at some mines) and lead is very important to the viability of a number of Canadian mines.

Roughly half of lead mine production is smelted and refined in Canada, at either the Cominco, Trail, B.C., plant (119,300 tonnes in 1981) or at the Brunswick, Belledune, N.B., plant (49,118 tonnes in 1981). Over half of metal production is exported, predominantly to the U.S. and the U.K., the world's two major producers of lead antiknock additives. Cominco has stated that about 20% of its lead metal production is used in such additives in Canada and abroad, and Brunswick's share (sold through Noranda Sales Ltd.) currently is about the same. The remaining mine output is also exported, mainly to Japan and Europe.

Several secondary lead smelters in Canada have a combined capacity of over 122,000 tonnes per year of lead but operate at only a fraction of this level owing to limited scrap supply.

Canadian lead mine and smelter production has shown a modest and irregular decline over the past decade. Current mine capacity is about 400,000 tonnes per year (including the Polaris mine); annual production therefore could increase significantly over the next year or so provided market conditions improve. A number of important deposits occur in Canada that could be developed in the medium to longer term, but this would require a significant increase in lead and/or zinc prices from their current, very depressed levels. Production potentially could exceed 400,000 tonnes per year by 1990. However, most undeveloped deposits are in relatively remote regions of the Yukon, Northwest Territories and British Columbia, and their development would entail very large infrastructure costs, and probably production costs well above those at existing mines.

No new lead smelters are expected to be built in Canada until at least towards the end of this decade. However, Cominco is considering costly modernization of its Trail smelter and, possibly, expansion to 200,000 tonnes per year. If this takes place, Canada's refined lead production could grow from 168,000 tonnes in 1981 to 230,000-250,000 tonnes per year by the mid-1980s. One problem with the Trail smelter is that its location is unfavourable with respect to newer lead mines and it is increasingly processing imported concentrates. There is some potential for a new smelter in B.C. or the Yukon in the late 1980s; if built, lead metal production could exceed 300,000 tonnes per year in the early 1990s.

Employment at mines producing lead totalled 10,333 in 1980 (see Table 2), while employment at primary lead smelters and refineries totalled 1590. Employment at secondary smelters is not available but probably totals another 200-300. While the mines in Quebec, Ontario and Manitoba produce relatively little lead, those mines in other provinces where lead is very important to mining viability employ about 60% of the listed mine employment.

According to SRI, Canada's primary lead production costs^a in 1981, in comparison with other major producing countries, were approximately on par with those of the United States (about U.S. 19¢/lb) but higher than those of such key competitors as Australia (15¢), Peru (14¢) and Mexico (9¢) at their current production levels. Projections for 1985 and 1990 indicate that Canada's relative cost disadvantage will increase over the next decade, particularly compared with Mexico, Peru and Australia but also with the U.S. These lower cost producers have the potential to considerably expand their output without commensurate cost increase, whereas new production in Canada faces production costs well above those at existing mines.

^a Unlike other cost estimates in the literature that estimate production costs after deducting by- or coproduct credits, SRI assigns a cost to each product in proportion to its contribution to ore value. Costs are direct operating expenses only.

TABLE 2 EMPLOYMENT AND PRODUCTION AT "LEAD" MINES AND SMELTERS/
REFINERIES IN CANADA, 1980 (From Mineral Policy Sector/EMR)

Mines (Number)	Employment	Production		
		Lead	Zinc	Other
		(t x 10 ³)		
Newfoundland (1)	316	3.8	6.6	Cu,Ag
Nova Scotia (2)	245	10.6	5.0	Ag
New Brunswick (2)	1,735	61.5	184.7	Cu,Ag,Au
Quebec (1)	133	0.2	7.9	Ag,Au
Ontario (4)	2,930	15.3	314.6	Cu,Ag
Manitoba (several)	1,647	1.6	35.3	Cu,Au
Saskatchewan (1)	Included with Manitoba			
British Columbia (6)	1,625	77.8	74.1	Ag,Cu,Au
Yukon (2)	1,002	75.3	109.2	Ag
Northwest Territories (2)	700	71.4	226.3	Ag
Total Mines	10,333	307.0	958.9	
<u>Smelters/Refineries</u>				
New Brunswick	590			
British Columbia	1,000*			
Total Smelters/Refineries	1,590			
Total	11,923			

* Total employment at the Trail lead-zinc-fertilizer operations was 4693. The company estimates that 1000 jobs are associated with lead production and marketing.

Lead Antiknock Additives in Canada

Antiknock additives are produced by Ethyl Canada Inc., near Sarnia, and Du Pont Canada Inc., at Maitland, Ont. Together they account for about a tenth of Canada's lead consumption, down from a fifth in 1970. Details are:

	Built	Antiknock Capacity (million lb./yr)	Equivalent Lead (tonnes)	Directly Associated Employment
Ethyl	1956	60	10,900	179
Du Pont	1965	40	7,300	137

Current production rates are about 60% of combined capacity. Ethyl also produces ethyl chloride, an antiknock raw material, and ethyl dichloride, an associated gasoline additive. Du Pont purchases these products from Ethyl. Both import metallic sodium (the third major antiknock raw material), ethyl dibromide and other additives from the U.S. Both obtain lead from both Cominco and Noranda (Brunswick Mining and Smelting), but Ethyl buys predominantly from Cominco while Du Pont buys mainly from Noranda. Both use some secondary metal obtained through the treatment of antiknock production residues, but antiknock production requires high purity lead and therefore most lead used is primary lead.

Canada's export trade in antiknock additives is small, although the U.S. and U.K. are significant exporters. Canadian producers have exported limited (and sporadic) amounts through their U.S. parents but they do not regard this as a reliable marketing opportunity. Their branch-plant status, tariffs and possibly lower scale economies than U.S. plants may be factors, but such trade also requires dedicated containers (because of contamination) and is probably not very competitive in small volumes. The U.K. producer, for example, which exports some four-fifths of its output, uses dedicated ocean vessels exclusively for this trade. Much of this trade is also with foreign subsidiaries of partners in the U.K. producer.

Use of lead in antiknock production in Canada peaked in 1973 at 19,128 tonnes and has since declined steadily. Under a 1974 regulation, the maximum permitted concentration of lead in gasoline is 3.5 g/I.G., but actual average content in leaded gasoline was 2.141 g/I.G. in 1979 (some refineries reach the maximum in winter but average use is well below the limit in summer).

Future trends in lead consumption will depend on overall gasoline consumption, the grade split between leaded and unleaded gasoline, and amounts of lead antiknock used in leaded fuel. The following analysis draws from 1981 forecasts by seven petroleum, automotive and additives producers. Gasoline consumption in Canada has fallen significantly since its 1980 peak and, while this is attributed in part to economic conditions, all the above predict a continuing decline through the 1980s. The predicted average drop over the decade (from 1981 levels) ranges from 1.5 to over 4% annually, with the average being about 2.3%.

Unleaded gasoline consumption grew quickly following its introduction in the early 1970s, to 3% of total gasoline in 1975 and to 42% in 1980. By 1990, and assuming no change in current lead content regulations, this share (regular plus premium unleaded) is projected to rise to about 65%.

Translating these trends into use of lead in gasoline in Canada, and assuming that average lead content of leaded gasoline remains at its 1979 level, lead usage would be as follows (ignoring exports of both lead additives and leaded gasoline):

	1980	1985	1990
Gasoline consumption ($m^3 \times 10^6$)	39.0	34.1	30.3
% leaded	60	42	35
Lead use ($t \times 10^6$)	10.9	6.67	4.94

Under the above assumptions, lead use in gasoline in Canada will fall from 10,900 tonnes in 1980 to about 4900 tonnes in 1990. The declining share of leaded to total gasoline is the most important factor; even if gasoline consumption remained constant through to 1990, lead use would still fall to below 6400 tonnes in that year.

Implications of Declining Lead in Gasoline for the Canadian Lead Industry

Lead consumption for gasoline additives - and for many other uses - has declined significantly in the Western World over the past 8 years. Growth in batteries and a few newer uses has offset these market losses, but not fast enough to permit any expansion in mine output in competition with growth in lead recycling. These patterns are expected to continue over the next decade or more; Western World mine production is likely to show little growth. Consumption in Canada will generally match the above pattern; it is clear that, contrary to Environment Canada's assessment, alternative markets will not exist in Canada for lead sales lost as the result of any phase-down of lead in gasoline. Such lost sales will have to be made up by larger exports, at additional cost and in competition with producers elsewhere, some of which enjoy lower production costs than the Canadian industry.

Lead supply and demand, as for other metals, are highly price inelastic in the short run but supply, at least, is elastic in the longer term. Past consumption trends indicate that the longer term demand is also strongly affected by technical and regulatory, as well as price, factors vis-à-vis substitutes. New mine development is likely to continue to occur where cost conditions are favorable, and this will intensify international competition for nearly static markets.

As of 1982, markets for lead in gasoline in Canada have fallen by about 10,000 tonnes per year compared with their 1973 peak. Even with no reduction in the 1974 lead-in-gasoline regulations, forecasts suggest that an additional 4300 tonnes per year could be lost by 1990, leaving total sales in the order of only 4900 tonnes per year by that time. If so, the cumulative market loss over the decade will total some 36,000 tonnes, compared with the 1980 consumption level. Some authorities have suggested that economic and energy conservation considerations will result in an easing of restrictions on leaded gasoline (as may be occurring in the U.S.) and consequently a slower loss of lead markets, but medium term oil and gas supply prospects are likely to dampen such pressures.

It is in this context that the implications of a more rapid phase-down in leaded gasoline must be assessed. Obviously, such a policy would have commensurate negative impacts on the remaining domestic market for lead in

gasoline during the coming decade. The lead producing industry is also very concerned about potential domino effects in other countries if a major lead producer such as Canada decided on an accelerated phase-down. Indeed, because of its key role in the international lead industry, Cominco rates the latter as its most serious concern in relation to any further phase-down in Canada.

Despite the projected domestic market loss of 36,000 tonnes of lead over the 1980s, forecasted consumption for lead in gasoline still totals 81,000 tonnes over the decade, including 51,000 tonnes over 1983-1990. It is the latter tonnage that would be affected by an accelerated phase-down.

Canadian lead producers enjoy a competitive advantage over their foreign competitors in the domestic market, owing to transport costs, tariffs (Canada's MFN rate on unwrought metal is free compared with 3.5% in the U.S. and E.E.C.) and other factors. Any loss of domestic markets entails higher transport, marketing and tariff costs for substitute sales abroad, estimated to total about \$100/tonne or 10-15% of sales revenues. Competitors from developing countries may enjoy additional advantages from trade preferences in developed countries and from emerging trade arrangements between developing countries where much of the future growth in lead consumption is expected to occur.

Notwithstanding these disadvantages in export markets, Canada's two primary refined lead producers expect to find alternative markets for lead sales lost in domestic antiknock production. If so, the major financial impact of accelerated phase-down will be the additional cost of alternative sales abroad. At an estimated \$100/tonne (\$1982), the forecast decline in domestic lead sales for gasoline additives will involve revenue losses to producers of some \$3.6 million over the 1980s. An accelerated phase-down that, say, sought complete phase-out over the 1983-1990 period in a linear pattern could increase the volume of lost domestic lead sales by an additional 18,000 tonnes, representing a further revenue reduction of nearly \$2 million, assuming that alternative markets are in fact found, and that the price effects of this market shift are negligible (the actual phase-out pattern would likely be a gradual acceleration in lost lead usage for several years, then tapering off towards 1990).

Financial analysis of each lead producer would help to assess how such revenue losses would affect mine and smelter profitability, production life, employment, tax revenues and the like, but such analysis would be complicated and probably not very conclusive due to the joint production characteristic of "lead" mines. Reduced revenues could shorten the lives of some mines, render some potential new mines uneconomic, and discourage investments to modernize and expand Canada's domestic lead smelters and refineries, but the overall impact on, say, employment would not be very large so long as producers are able to find alternative markets offshore.

Perhaps the major question that needs addressing, however, is that given a projected significant phase-down in the use of leaded gasoline to near negligible levels in Canada by the end of the present decade, why is it necessary to consider any further acceleration? Certainly, present economic circumstances in lead and other industries make the timing of such a decision most inopportune.

Mining Policy Sector
Energy, Mines and Resources Canada
June 9, 1982

Post-script Appended by EMR

Since this paper was written, the price of lead has continued to decline to the lowest level in real terms in decades, lead stocks have risen to all-time record highs and consumption continues to be sluggish or declining around the world.

APPENDIX C

GASOLINE DEMAND FORECAST

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GASOLINE DEMAND FORECAST

C.1 GENERAL

Since the investigation of options for lead phase-down in motor gasoline was first initiated, several gasoline demand forecasts have been put forward. Although the nature of the assumptions incorporated in the various forecast models are essentially the same, the values applied to the assumptions (e.g., crude oil price, average annual kilometres per vehicle, etc.) have differed, with the result that the projections also differed, in some cases substantially.

One of the most significant considerations has been whether or not - and to what extent - the downturn in total gasoline demand, first apparent in 1981 and continuing through to the present, was taken into account. More recent forecasts (NEB and Du Pont's ESCON model) project volumes through to the year 1995 which differ significantly from those forecast 3 years ago.

It is therefore desirable to select a forecast which reflects updated assumptions and which addresses most concerns. This is not to say that opinions will not differ and that there will not be arguments in favour of one or another of the recent forecasts. However, it is to be recognized that the intent of the forecast chosen is to estimate, among other factors, total lead emissions under the status quo and, similarly, the reduction in emissions achieved under each of the alternative options. Therefore, the end result of a minor change in total gasoline demand (and likewise in the volume split between leaded and lead-free grades) is a corresponding change in lead emissions (or reductions). If the forecast is directionally valid, its purpose should then be served.

The major assumptions that were considered when projecting the base forecast for total gasoline demand used in this report are elaborated below. Other forecasts generated during the investigation of lead phase-down options will be identified and the major reasons for the differences among these briefly explained. For ease of comparison, these forecasts will also be graphed.

C.2 DEMAND ASSUMPTIONS

Gasoline requirements are dependent upon three primary assumptions, namely:

- the size and growth of the gasoline fleet, including gasoline-powered automobiles and light-, medium- and heavy-duty trucks;
- the fuel efficiency of the gasoline fleet which, in turn, is dependent upon the age of the fleet, the state of engine technology, government regulations with respect to emission levels, and other variables; and
- the average annual vehicle kilometres driven, which is largely a function of the price of gasoline and of income levels.

Gasoline Fleet

In 1979, the Canadian gasoline-powered fleet consisted of approximately 9.5 million automobiles and an estimated 2.5 million gasoline-powered trucks and commercial vehicles, for a total of 12.0 million gasoline-powered vehicles (42). The automobile fleet grew at an average rate of 4.8% annually during the period 1968 to 1979, as did gasoline-powered trucks and commercial vehicles.

It is anticipated that the growth rate in the gasoline-powered fleet will not be as rapid over the next decade as it has been historically. The primary reasons for this decreased growth rate are:

- saturation levels of ownership among the car-owning population (all persons over 20) are being approached. The ratio of the car-owning population to registered automobiles has declined from 2.5 in 1960 to approximately 1.5 in 1979; for the last 3 years the ratio has been stable. Therefore, the growth in the fleet will depend upon the growth of the car-owning population. Statistics Canada has estimated this growth to be 2%-3% through the 1980s. This may be considered as the maximum growth rate expected for the automobile fleet through the decade, and represents approximately 50% of the historic growth rate of 4.8% (42);
- the other major determinant of the growth of the automobile fleet is the cost of car ownership, including both the initial capital cost and the ongoing cost of operations (primarily fuel and maintenance). Both cost components of car ownership have been increasing in real terms. Capital costs, strongly affected by interest rates, have shown significant real increases in recent years, although these have moderated somewhat in past months. Fuel costs were expected to increase in real terms; this outlook no longer appears to be true, with fuel prices now projected to increase only in nominal terms (44).

In summary, the main determinant of fleet growth would appear to be the relationship of registered automobiles to the car-owning population; the effect of capital costs and fuel prices upon the cost of car ownership, conversely, would appear to have been neutralized.

The rates of growth demonstrated by gasoline-powered trucks and commercial vehicles will also decrease. Increases in dieselization and in alternative fuels, such as propane, for commercial fleets will influence this segment of the vehicle fleet. Overall, the gasoline-powered fleet is expected to increase from 12 million vehicles in 1979 to 16.6 million vehicles in 1990 (a 25% overall increase)(57).

Fuel Efficiency

Fuel efficiency of the gasoline fleet depends primarily upon the age of the fleet and the mix of vehicles and engine sizes. Other individual

factors, such as driving habits, length of trips and maintenance of vehicles, also affect fuel efficiency, but not to the same extent.

Statistics regarding the age of the Canadian automobile fleet (42) indicate the following:

- while they have reached a high of 14% and a low of 9%, new car registrations, as a percent of total car registrations, have remained relatively constant at approximately 10% since 1974;
- in 1979, 50% of the vehicles in the Canadian gasoline fleet were 4 years old or less, with almost all vehicles in the fleet being 11 years old or less. (Western Canada has a slightly older fleet than the rest of Canada.)

This infers that the average vehicle life is 10 years, that the entire fleet will theoretically be replaced every 10 to 11 years, and that by 1990 the oldest vehicles in the fleet will be 1979 models.

In 1981, 72% of new cars registered in Canada were produced in North America. In Canada, legislation has been passed prescribing a voluntary company average fuel consumption (CAFC) standard of 8.6 L/100 km (33 miles/imp. gal.) to be met by all new car sales by 1985. In the U.S. market, automobiles are subject to regulations administered by the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA). U.S. automobiles must, by 1985, meet a similar corporate average fuel economy (CAFE) standard of 8.6 L/100 km (27.5 miles/U.S. gal.) (58).

Thus, new cars entering the fleet will have improved fuel efficiency over the vehicles presently in the fleet. It can be reasonably expected that the new cars produced and sold in Canada will show the same level of fuel economy improvement as their American counterparts. For the nearly 30% of the new car market represented by imports, it is likewise assumed that the fuel economy will be at least as high as North American automobiles.

New car registrations within the fleet are significant in terms of their impact upon gasoline consumption. From 1968 to 1978 it was estimated that the fuel economy of the car fleet as a whole improved on average by little more than 0.1% annually (from 17.58 mpg to 17.75 mpg). For the period 1979 to 1990, however, it is estimated that fuel economy will improve by 3.5% annually (from an average of 17.96 mpg to 26.28 mpg, or 15.7 L/100 km to 10.7 L/100 km)(43). These are figures for the gasoline fleet as a whole, reflecting the expected mix of size (including engine) and age of vehicles. Therefore, without any change in the size of the fleet or the average number of miles driven, there would be a decline in the amount of gasoline required.

Average Vehicle Kilometres

No reliable statistics exist for the average number of kilometres driven by the Canadian fleet. The National Energy Board (NEB) and Environment Canada estimated that the average annual vehicle mileage in 1976 was 9400 miles (15,000 kilometres) (2). The NEB model postulates that the average distance

driven is a function of the size of the automobile and the age of the car. Larger vehicles are assumed to be driven further with annual use declining with the age of the vehicle across all classes of automobile size. Other studies estimate 16,000 km/annum (42).

When forecasting gasoline sales, the demand models developed by the Department of Energy, Mines and Resources (EMR) and NEB both used a unitary elasticity with respect to the income of the population and a negative price elasticity with respect to the price of gasoline (60,59). Thus, as the overall level of Canadian income changes, the consumption of gasoline is expected to change by a proportional amount. The other component of demand determination, the price of gasoline, serves to decrease the demand for gasoline as the price increases in real terms. Until recently, it was thought that real price increases forecast in the National Energy Program would, because of this price elasticity, result in a decreased demand for gasoline and therefore decreased kilometres driven. Again, the outlook appears to have moderated somewhat; although there has been no official update, government representatives indicate prices will rise in nominal rather than in real terms (44).

Summary of Gasoline Requirements Forecast Assumptions

The major assumptions affecting gasoline requirements can be summarized as follows:

- the size of the gasoline fleet will continue to increase, but at approximately half the historical rate;
- the gasoline fleet's fuel economy will improve by approximately 3.5% annually over the decade;
- the cost of operating a vehicle will not increase, or increase by only a minor amount, in real terms, when the revised outlook vis-à-vis capital costs and fuel prices is taken into account.

These assumptions will have the following impacts upon the demand for gasoline:

- moderate increases in the gasoline-powered vehicle fleet will lead to increases in the demand for gasoline;
- an improvement in gasoline fleet fuel economy through the modernization of the fleet will lead to a decrease in demand for gasoline;
- any increases in the cost of operations will be offset by increases in Canadian income levels and result in a return to the historical number of kilometres driven per year.

NEB is predicting that the net result of these forces is a decline in gasoline requirements through the 1980s followed by an upturn as consumers' income levels improve and as they adjust to higher fuel prices (61).

C.3 COMPARISON OF FORECASTS

Forecasts of total Canadian gasoline demand generated over the past 3 years have changed progressively as the key assumptions, and their values, were revised. The result has been that the more recent forecasts project reduced total demand when compared to earlier forecasts.

Until 1980, total gasoline demand had been on the increase. Starting in 1980, however, and continuing through to the present^a, a decline in actual gasoline consumption has been apparent (62). The extent to which this was taken into account is the primary difference between the earlier and more recent forecasts.

The exact causes of this decline are difficult to pin down. Although a contributing factor, it is unlikely that the drop resulted exclusively from improvements in fuel economy. Rather, new car registrations during 1980 and 1981 were down 7% from the average of the preceding 8 years; it is therefore probable that much of the decline is attributable to the economic recession. NEB estimates that the volume decline of 8%, 1982 vs 1981, was made up of 3.5% due to fuel economy and the balance due to the recession (44).

A sampling of various forecasts follows. Figure C.1 illustrates the difference in projections.

Energy, Mines and Resources

In December 1980, EMR prepared a forecast which, because it was done prior to the decline in consumption became fully apparent, projected a moderate downturn but an otherwise stabilization of demand through to the 1990s (60). Total gasoline sales in 1995 were estimated to be 36.1 billion litres.^b

This forecast, because it predicted the highest demand levels of those discussed, is frequently referred to as the "high requirements scenario". The estimates made by MHG of capital and operating costs to be incurred by the refineries were based on 1979 volumes. However, it was argued that the cost estimates were directionally valid and reflective of costs to be incurred because total volumes projected by EMR for 1986 (the assumed earliest data of implementation) were only 5% below 1979 gasoline volumes (43,48).

Therefore, inasmuch as more recent forecasts predict that total gasoline demand will be somewhat less than the volumes used in MHG's model, MHG's cost estimates may be regarded - at least within the context of the model's parameters and assumptions - as being maximum cost estimates.

^a Gasoline sales for the first 5 months of 1983, as provided by Ethyl Corporation in the Aug. 1, 1983, issue of Oilweek, show a 4.2% decrease (total national) vs the same period 1982.

^b It should be noted that still earlier forecasts were generated by NEB, EMR, Du Pont and Ethyl in the period 1978-79. These are presented in MHG International Ltd.'s "A Study on the Incremental Refinery Construction Costs Associated with the Reduction in the Amount of Lead Additive in Gasoline," Table 5-4, page 181.

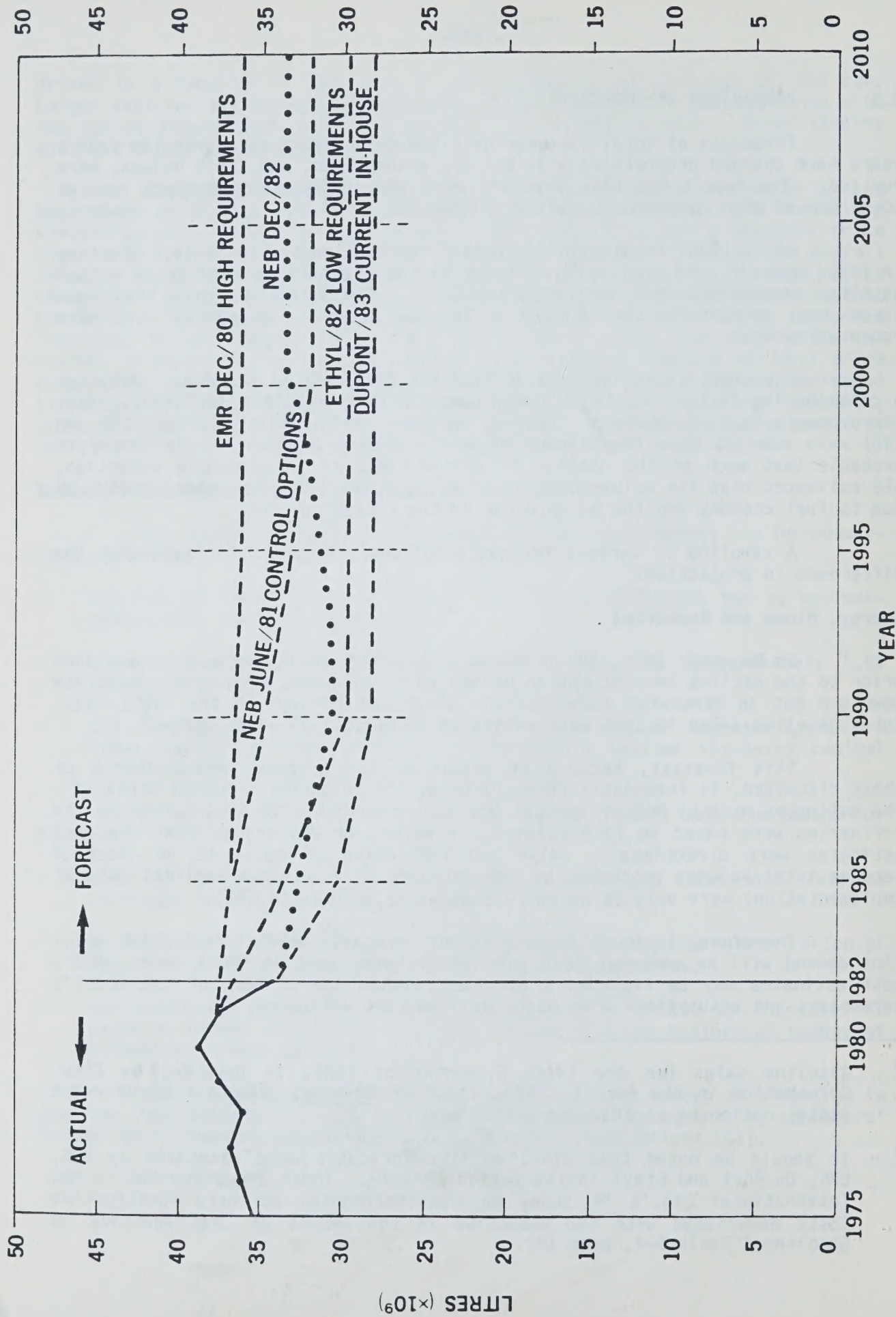


FIGURE C-1 COMPARISON OF TOTAL GASOLINE DEMAND FORECASTS

Control Options Report

The report, issued in February 1983, entitled "Control Options for Lead Phase-down in Motor Gasoline" (2) used a forecast generated by NEB in 1980 and published June 1981 as the basis for its projected gasoline demand (59). Du Pont's ESCON computer program was then used to develop demand forecasts for leaded and lead-free gasolines (63). The estimated total gasoline sales for 1995 were 34.2 billion litres, only marginally less than the EMR forecast.

Ethyl

Ethyl prepared a gasoline demand forecast after the 1981 decrease became more apparent (64). In contrast to the EMR and NEB/Control Options Report forecasts, this projection, referred to as the "low requirements scenario", continued the demand decrease of 1981, with a levelling off of sales occurring toward the end of the decade. Estimated requirements for 1995 were 29.5 billion litres, significantly less than previous forecasts.

Du Pont

In October 1982, Du Pont generated a forecast using their ESCON model which estimated that by 1990, total gasoline demand would be 30.9 billion litres (65). Assuming a stabilization of demand through the 1990s (beyond the horizon of the ESCON model), this is virtually identical to NEB's 1982 forecast of 31.0 billion litres.

The assumptions incorporated in Du Pont's ESCON model (66) are that:

- consumption is falling because people are driving less and thus consuming less fuel;
- constraints upon growth in real income (resulting in decreased purchases) will be balanced by a moderation of fuel price increases and a decrease in the real cost of driving (therefore increased purchases);
- vehicle fuel economies are improving more rapidly than expected, and are the primary force behind the decline in projected demand;
- similarly, improvements in fuel efficiency will be largely exhausted by the late 1980s, with the result that volume demand is expected to level off through the remainder of the century.

National Energy Board

A somewhat higher projection was made by NEB in December 1982, predicting a 1995 total gasoline demand of 31.0 billion litres (45). Directionally, the assumptions used by NEB are largely in accord with those used by Du Pont. NEB, however, show an upturn commencing in 1990 and beyond, the reasoning for this being that crude oil prices at the refinery gate, they believe, will decrease in the order of 15-20% when compared to the prices projected in the National Energy Program (October 1980) and incorporated in NEB's July 1981 gasoline forecast.

It is assumed that the effect of lower crude costs and moderating growth in gasoline prices, notwithstanding the other assumptions described above, will be to reverse the present trend of declining gasoline purchases and also create a tendency to somewhat larger (higher fuel consumption) vehicles compared to those penetrating the fleet during the 1980s (61).

Recent Forecasts

A more recent series of forecasts hypothesize that future gasoline demand will be even further reduced. Forecasts typical of this current outlook have been generated by ILZRO in May 1983 (56), PACE in May 1983 (51) and Du Pont (current in-house projection) (67). Estimates of 1990 total gasoline sales are 28.8, 28.8 and 28.6 billion litres, respectively; the first two forecasts do not project beyond 1990, whereas Du Pont now predicts that the 1990 volume will be maintained through to 1995.

C.4 BASE FORECAST

The forecast used within this report as the basis for calculating lead emissions under the various options is the NEB forecast of December 1982. The fundamental reasons for this follow:

- The assumption that a relative decline in oil prices could give rise to increased consumption and a tendency towards larger cars is plausible, recognizing that the converse was previously given as the reason for the decline in demand during the 1980s depicted by all earlier forecasts.
- An NEB energy demand forecast may be regarded as an official national projection.
- Whereas the NEB forecast predicts levels of gasoline demand marginally higher than those contained in other recent forecasts, the choice of the higher of the alternatives (as with the use in this report of a maximum allowable lead content under the status quo) is in accord with generally accepted environmental impact assessment principles. These assumptions produce maximum estimates of lead emissions.
- Thus, the level of emissions under one or another of the phase-down options will represent maximum emissions under that option. Therefore, any change to this base forecast - and to the levels of emissions - will likely result in lower rather than higher estimates, and thus be an improvement upon the base case presented.
- An in-house but unofficial EMR forecast predicts the same stabilization during the latter part of the 1980s and then upturn, with volumes only marginally off those forecast by NEB (46).

C.5 RATIO OF LEADED TO LEAD-FREE GASOLINE

The breakdown of total gasoline demand into grades of leaded and lead-free is a function of several factors:

- the production of catalyst-equipped, lead-free fuel burning passenger automobiles and light-duty trucks (under 2700 kg) as a result of automotive exhaust emission regulations;
- conversely, the production of leaded fuel burning automobiles that can meet the emissions standards without a catalytic converter;
- misfuelling of lead-free designated vehicles;
- the segment of the vehicle population that is exempt from emission regulations (medium/heavy-duty trucks).

Emission Standards

The introduction in the early 1970s by Canada and the U.S. of automobile emission standards in order to combat air pollution problems - as well as the fuel consumption standards enacted in the U.S. - has had two major impacts on the North American automobile manufacturing industry, namely the use of catalytic converters and a reduction in engine compression ratios.

Since 1975, U.S. manufacturers have elected to use the catalytic converter, or "after burner", in the exhaust system as the best means of meeting the emissions standards. However, the use of the catalytic converter on new automobiles means that these vehicles are not able to use leaded fuel because lead poisons the converter and renders it ineffective in reducing hydrocarbon (HC) and carbon monoxide (CO) emissions. At this time, approximately 80% of new automobiles sold in Canada are equipped with catalytic converters and, therefore, require lead-free fuel (2).

Under sustained pressure by the U.S. government, the automotive and petroleum refinery industries have agreed to produce engines with compression ratios of between 8:1 and 9.4:1, and a gasoline with an octane number of 91 to 92 as the appropriate compromise among refinery cost, engine efficiency, fuel consumption and emission standards. The reduction of the compression ratio reduces the peak cylinder temperature but raises the cylinder exhaust temperature, thereby reducing the formation of hydrocarbon, carbon monoxide and nitrogen oxide (NO_x) emissions.

Although there have been indications of a relaxation of emission regulations in the United States, it does not appear that there will be any alternative to the catalytic converter in the foreseeable future. If the 1981 standard of 1 gram per mile (g/mi.) of NO_x is relaxed to 2 g/mi., this would only allow for the change from a 3-way converter to a 2-way oxidation converter. Therefore, the majority of new automobiles manufactured for the North American market, it is assumed, will be equipped with a catalytic converter and will require lead-free gasoline.

Leaded Fuel Automobiles

Currently, all new automobiles sold in the U.S. must use lead-free gasoline. However, because of the less stringent Canadian emission standards,

it is possible for automobile manufacturers to produce a car which meets these standards without the use of a catalytic converter. Added incentive to do so is provided by the price differential between leaded and lead-free gasoline; some Canadian manufacturers have therefore modified the U.S. automobile design (while maintaining the same compression ratio) to meet Canadian emission standards without a catalytic system. This provides automobile manufacturers with a market strategy based on some consumers' perceived advantage of leaded vehicles over competing lead-free models because of the ability to burn less expensive leaded gasoline.

At present, the majority of Chrysler Canada's models are designed to run on leaded fuel and without a catalytic converter. General Motors of Canada offer a couple of "leaded" models, including the Chevette, although it is understood that this is treated as a factory option. The car has a different transmission because of engine loading, and dealers have been instructed to tell prospective buyers that there is a 4% fuel consumption penalty (66).

Whereas Chrysler has indicated that they intend to continue to market in Canada automobiles that are leaded-fuel burners and not equipped with catalytic converters, both General Motors and Ford have indicated that they wish to market cars that are catalyst equipped and not to produce a car specifically designed for the Canadian market (68). This allows the manufacturers to capture economies of scale - both in design and production stages - and allows for the free interchange of automobiles between the Canadian and U.S. markets.

Misfuelling

Misfuelling is the use of leaded gasoline in a vehicle otherwise designated as lead-free. The cause of misfuelling is the availability of lower-cost leaded gasoline, compounded in some areas (such as rural Western Canada) by the practice of bulk purchases of one grade of gasoline which is then used for a variety of vehicles.

In the Control Options report, Environment Canada estimated a misfuelling rate of 6-7% (2). It was indicated that this could be interpreted as meaning that either all vehicles were misfuelled 6-7% of the time, or 6-7% of vehicles are misfuelled all of the time. It was concluded that the latter case is the more probable situation.

Futhermore, it should be noted that because the catalyst is rendered inoperative by misfuelling, HC and CO emissions are estimated to increase by a factor of five. Environment Canada calculated that the 6-7% misfuelled vehicles give rise to at least a 20% increase in nationwide automotive emissions of HC and CO.

More recent estimates of misfuelling are in the order of 10%; there is even speculation that this could increase to 15% with the growth in the lead-free designated vehicle population (69).

Projected Grade Split

While the total gasoline demand projection contained in Environment Canada's Control Options report was based upon NEB's 1981 outlook, forecasts

for leaded and lead-free gasoline were generated using the Du Pont ESCON computer program (63). The demand for each grade of gasoline (regular leaded, and premium and regular lead-free) is calculated by summing the demand for each of gasoline-powered automobiles, light trucks and medium/heavy-duty trucks. This demand by vehicle class is in turn based upon consideration of the number of vehicles in each class, their fuel type, the scrappage rate, annual kilometres driven, and fuel consumption.

The Control Options Report predicted that leaded gasoline sales would continue to decline as a result of new catalyst-equipped automobiles penetrating the fleet. Based on industry's advice, it was estimated that, by 1988, 87% of passenger-automobiles and light-duty trucks less than 2700 kg would be using lead-free gasoline, while the balance would burn leaded gasoline (2). The balance of the leaded gasoline fleet is comprised of medium/heavy-duty trucks over 2700 kg for which there are currently no emission standards. They are therefore not catalyst-equipped and burn leaded gasoline.

Taking into account a 6-7% misfuelling rate, Environment Canada estimated that by 1988 only 30% of the gasoline pool would be leaded. They further assumed that this grade split, lead-free vs leaded gasoline, would continue into the future because of a stabilization of the composition of the leaded fleet.

It has already been noted that the base forecast of gasoline demand chosen for this report differs from the forecast contained in the Control Options Report. Even if the same timeframe for realizing the grade split in lead-free and leaded grades is maintained, this automatically means a change in their respective demand levels.

Whereas there was a rapid annual growth in the mid- to late 1970s in the percentage of total gasoline accounted for by lead-free gasoline, the year-to-year change in the early 1980s appears to have slowed somewhat in comparison, leading one to suspect that 1988 may in fact be too early a target for attaining the 70/30 split. Table C-1 illustrates this point. Whether this moderation in grade split change is due to the fuel efficiency of new lead-free burning vehicles, a reduction in new car registrations, increased misfuelling, and/or the advent of some new (albeit few) lead-tolerant vehicles is difficult to say.

TABLE C-1 YEAR-TO-YEAR CHANGE IN LEAD-FREE SALES AS A PERCENTAGE OF TOTAL GASOLINE SALES

YEAR	Percent Lead-free of Total Gasoline Sales	Percent Change of Lead-free/Total Sales Year to Year
1974	1.4	-
1975	5.8	4.4
1976	10.6	4.8
1977	15.3	4.7
1978	22.3	7.0
1979	33.2	10.9
1980	37.6	4.4
1981	41.3	3.7

Although only slightly different from the Control Option Report's date of 1988, a more likely date may well be 1990. This is supported by Du Pont's current in-house ESCON run (67) and would appear to fall in line with the NEB base forecast assumptions with respect to stabilized growth in the 1980s followed by an upturn in the 1990s. The proposed grade split is illustrated in Table C-2.

TABLE C-2 GASOLINE SALES FORECAST AND GRADE SPLIT (NEB, December 1982 Forecast (total gasoline) (ref. 45))

Year	Total Gasoline		Leaded (Incl. Premium)		Lead-free (Incl. Premium)	
	Vol. (L x 10 ⁹)	Percent	Vol. (L x 10 ⁹)	Percent	Vol. (L x 10 ⁹)	Percent
1975 ^a	35.4	100	33.4	94	2.0	6
1980 ^a	38.2	100	24.2	63	14.0	37
1981 ^a	37.3	100	22.0	59	15.3	41
1982	33.9	100	19.8	58	14.1	42
1985	32.8	100	14.8	45	18.0	55
1990	30.7	100	9.2	30	21.5	70
1995	31.0	100	9.3	30	21.7	70
2000	33.5	100	10.1	30	23.4	70
2005	33.5	100	10.1	30	23.4	70
2010	33.5	100	10.1	30	23.4	70

^a Actual volumes and grade split

A more detailed breakdown is provided in Table C-3; it also provides a breakdown of leaded gasoline use by vehicle type under the status quo, as well as incremental lead-free gasoline sales resulting from the penetration of new vehicles under a lead-free option (based on an annual sales/turnover factor of 10% of the existing fleet).

C.6 LEAD USAGE AND EMISSIONS UNDER STATUS QUO

Concentration of Lead in Gasoline

During the period of 1975-81, the average levels of lead in leaded gasoline (premium and regular combined) were in the range of 0.44 to 0.46 g/L (2.0-2.1 g/gal.). Table C-4 shows the lead content for both grades of leaded gasoline as well as for the total gasoline pool.

Two points warrant clarification. Firstly, premium leaded gasoline in 1982 was approximately 1.4% of total leaded sales and was declining; therefore, the lead content of regular leaded gasoline is essentially the same as the average of the two leaded grades combined.

TABLE C-3 INCREMENTAL VOLUME CALCULATIONS (L x 10⁹) 1987-2006

YEAR	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL
1. Total Gasoline Demand	32.0	31.5	31.1	30.7	30.8	30.8	30.9	30.9	31.0	31.5	32.0	32.5	33.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	643.2
2. Lead-free Demand	19.4	20.1	20.8	21.5	21.6	21.6	21.6	21.6	21.7	22.0	22.4	22.7	23.1	23.4	23.4	23.4	23.4	23.4	23.4	23.4	443.9
3. Leaded Demand	12.6	11.4	10.3	9.2	9.2	9.2	9.3	9.3	9.3	9.5	9.6	9.8	9.9	10.1	10.1	10.1	10.1	10.1	10.1	10.1	199.3
STATUS QUO (Leaded)																					
4. Passenger Vehicles	5.9	5.4	4.8	4.3	4.3	4.3	4.4	4.4	4.4	4.5	4.5	4.6	4.6	4.8	4.8	4.8	4.8	4.8	4.8	4.8	94.0
5. Light Trucks	4.7	4.2	3.8	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	73.3
6. Medium/Heavy Trucks	2.0	1.8	1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	32.0
ALL LEAD-FREE																					
7. Passenger Vehicles																					
7.1 Lead-free Vol.	.59	1.08	1.44	1.72	2.15	2.58	3.08	3.52	3.96	4.5	4.5	4.6	4.6	4.8	4.8	4.8	4.8	4.8	4.8	4.8	71.92
7.2 Leaded Vol.	5.31	4.32	3.36	2.58	2.15	1.72	1.32	0.88	0.44	0	0	0	0	0	0	0	0	0	0	0	0
8. Light Trucks																					
8.1 Lead-free Vol.	.47	.84	1.14	1.36	1.7	2.04	2.38	2.72	3.06	3.5	3.5	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	55.91
8.2 Leaded Vol.	4.23	3.36	2.66	2.04	1.7	1.36	1.02	.68	.34	0	0	0	0	0	0	0	0	0	0	0	0
9. Medium/Heavy																					
9.1 Lead-free Vol.	0.20	0.36	0.51	0.6	.75	0.9	1.05	1.20	1.35	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	24.42
9.2 Leaded Vol.	1.8	1.44	1.19	0.9	.75	0.6	.45	0.30	0.15	0	0	0	0	0	0	0	0	0	0	0	0
10. Total Lead-free (7.1, 8.1 & 9.1)	1.26	2.28	3.09	3.68	4.6	5.52	6.51	7.44	8.37	9.5	9.6	9.8	9.9	10.1	10.1	10.1	10.1	10.1	10.1	10.1	152.25

TABLE C-4 LEAD CONTENT OF GASOLINES IN CANADA (g/L) (Environmental Protection Service (ref. 47))

Year	Premium	Regular	Lead-free	Total Pool
1975	0.66	0.45	-	0.45
1976	0.55	0.44	-	0.40
1977	0.55	0.42	-	0.36
1978	0.45	0.44	-	0.34
1979	0.44	0.47	-	0.32
1980	0.55	0.45	-	0.29
1981	0.68	0.46	-	0.28

Secondly, these are average lead levels representing total refinery production over the course of a given year. The Air Pollution Control Directorate's "Yearly Report of Lead Additives Usage in Refineries" for 1981 and 1982 indicates that average annual lead additive concentrations at certain refineries far surpass these current average levels for all refineries.

Nonetheless, assuming that no gasoline is produced with concentrations in excess of the regulated level of 0.77 g/L, the focus of our attention must be with the total average concentration for all refineries.

There is general agreement that a relationship exists between the concentration of lead additives in leaded gasoline on the one hand, and the volume of lead-free gasoline produced on the other. As lead-free production increases, refineries must use an increasing proportion of the available octane pool in order to maintain the desired octane levels of lead-free gasoline. Conversely, fewer octane barrels are available for the production of leaded gasoline, thereby necessitating higher lead additive concentrations to maintain the desired octane level.

However, there is disagreement over the concentration of lead additives that may be expected in the future, given current regulations. The Control Options Report assumed that by 1986 refiners would be adding the maximum 0.77 g/L. In contrast, PACE projected a maximum content of 0.60 g/L (51), whereas ILZRO projected 0.68 g/L by 1985 (56).

Industry have argued that closure of some older refineries reduces the necessity of increasing lead levels because of the more severe refining capacity of the plants that remain. Furthermore, they rightly question a 0.77 g/L average on the grounds that refineries would have to operate below this level simply in order to avoid exceeding it. On the other hand, ILZRO's assumption that industry would not exceed 0.68 g/L after 1985 is qualified by the statement that "a portion of the refining industry will be able to operate without going to the maximum lead content of 0.77 g/L. The balance of the refining industry will settle at a value below 0.77 g/L to ensure remaining at a legal lead level" (56). Implied in this statement, however, is that a portion of the refineries will in fact surpass the 0.68 g/L level.

There is, therefore, concurrence that lead levels will increase, but not on the amount of increase. In the final analysis, it is necessary to remember that the legal maximum is 0.77 g/L and that the refineries therefore have the leeway to increase lead levels up to this level at their discretion. Similarly, it is customary when assessing environmental impacts of this nature to reflect the regulatory maximum; the scenario presented therefore becomes the worst case under the status quo. Alternative scenarios subsequently are improvements upon this worst case.

Although it is recognized that the refineries would necessarily have to operate marginally under 0.77 g/L in order to avoid exceeding that limit, 0.77 g/L will nonetheless be used within this report for purposes of calculating lead emissions.

Lead Emissions

Based upon the foregoing assumption of a maximum permissible lead content of 0.77 g/L, total lead emissions are calculated for the years 1987-2006 and are shown in Table C-5.

TABLE C-5 LEAD EMISSIONS FORECAST

Year	Total Gasoline Demand (L x 10 ⁹)	Leaded Gasoline Demand (L x 10 ⁹)	Lead Concentration (g/L)	Lead Consumed (t x 10 ³)	Lead Emitted ^a (t x 10 ³)
1975 ^b	35.4	33.4	0.47	15.8	11.9
1980 ^b	38.2	24.2	0.45	11.0	8.3
1987	32.0	12.6	0.77	9.7	7.3
1990	30.7	9.2	0.77	7.1	5.3
1995	31.0	9.3	0.77	7.2	5.4
2000	33.5	10.1	0.77	7.7	5.8
2005	33.5	10.1	0.77	7.7	5.8
2010	33.5	10.1	0.77	7.7	5.8

^a Assumption that 75% of lead is emitted to the environment.

^b Emissions based upon actual (average annual) lead concentrations (from Control Options Report). 1987 and beyond projected upon current legal maximum of 0.77 g/L.

In 1987, at the assumed time of implementation of new regulations, lead emissions would be approximately 7250 tonnes; reduction of leaded gasoline sales will result in estimated lead emissions of 5800 tonnes by 2006. These will be lower still if the expected upturn in gasoline demand projected in NEB's base forecast does not materialize.

APPENDIX D

CONTROL OPTIONS

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CONTROL OPTIONS

D.1 GENERAL

Leaded Gasoline Vehicles

In order to estimate certain costs and benefits which are contingent upon the composition of the gasoline vehicle fleet (e.g., cost of lead traps and benefits derived from fuel and maintenance savings), a forecast and break-down of the gasoline vehicle fleet is required. Estimates required are:

- a forecast of the total gasoline vehicle fleet;
- leaded gasoline portion of total fleet, broken down by passenger cars, light-duty trucks and medium/heavy-duty trucks;
- leaded gasoline vehicle sales, commencing in the year 1987 (proposed year in which any lead control regulation would take effect) and broken down by vehicle type;
- cumulative sales of leaded vehicles, in total and by type, to illustrate the penetration of the fleet by these vehicles as of the regulatory date.

Table D-1 presents the estimates that were arrived at based on the following assumptions:

- **Total Gasoline Fleet:** From 1987 to 1990, the total gasoline fleet is derived from Du Pont's ESCON model (67). After 1990, the total fleet is escalated at a growth rate of 2.5% per year in line with Statistics Canada's estimate of growth in the car-owning population (42).
- **Leaded Gasoline Fleet:** At present, it is assumed that leaded gasoline vehicles account for 20% of total gasoline vehicle sales. This is a weighted average, comprised of leaded gasoline passenger cars at 13% of total passenger car sales, leaded gasoline light-duty trucks at 32% of total light-duty truck sales, and leaded gasoline medium/heavy-duty trucks generally assumed to be 100% of sales for that category. By 1987, this proportion of sales is assumed to be equivalent to the overall composition of the fleet; i.e., leaded gasoline vehicles will account for 20% of the total gasoline fleet. Passenger cars, light-duty trucks and medium/heavy-duty trucks, calculated as a percentage of the leaded vehicle fleet rather than the total gasoline fleet, are 48%, 38% and 14%, respectively (Table D-2). The numbers used as a basis for this calculation were again extracted from Du Pont's ESCON model.
- **Leaded Gasoline Fleet Sales:** Vehicle sales are estimated to be equivalent to approximately 10% of the total gasoline fleet existing at a given point in time; this correlates with the assumption that the average vehicle life is 10 years.
- **Cumulative Sales:** When estimating various vehicle-related costs and benefits resulting from the control options, the point of interest is the rate at which the vehicles affected, commencing with sales in 1987, accumulate and penetrate the fleet. The numbers shown are straightforward

TABLE D-1: FORECAST OF LEADED GASOLINE VEHICLES (vehicles x 10⁶)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Total Gasoline Fleet ^a	15.80	16.10	16.30	16.60	17.00	17.40	17.90	18.30	18.80	19.30	19.70	20.20	20.70	21.21	21.80	22.30	22.90	23.50	24.00	24.60
2. Leaded Gasoline Fleet ^b	3.16	3.22	3.26	3.32	3.40	3.48	3.58	3.66	3.76	3.86	3.94	4.04	4.14	4.24	4.36	4.46	4.58	4.70	4.80	4.92
Passenger Cars (48%)	1.52	1.55	1.56	1.59	1.63	1.67	1.72	1.76	1.80	1.85	1.89	1.94	1.99	2.04	2.09	2.14	2.20	2.26	2.30	2.36
Light-duty Truck (38%)	1.20	1.22	1.24	1.26	1.29	1.32	1.36	1.39	1.43	1.47	1.50	1.54	1.57	1.61	1.66	1.69	1.74	1.79	1.82	1.87
Med/Heavy-duty Trucks (14%)	.44	.45	.46	.46	.48	.49	.50	.51	.53	.54	.55	.57	.58	.59	.61	.62	.64	.66	.67	.69
3. Leaded Gasoline Fleet Sales ^c	.32	.32	.33	.33	.34	.35	.36	.37	.38	.39	.39	.40	.41	.42	.44	.45	.46	.47	.48	.49
Cumulative	.32	.64	.97	1.30	1.64	1.99	2.35	2.72	3.10	3.49	3.88	4.04	4.14	4.24	4.36	4.46	4.58	4.70	4.80	4.92
Pass. Cars (48%)	.15	.16	.16	.16	.16	.17	.17	.18	.18	.19	.19	.19	.20	.20	.21	.21	.22	.23	.23	.24
Cumulative	.15	.31	.47	.63	.79	.96	1.13	1.31	1.49	1.68	1.87	1.94	1.99	2.04	2.09	2.14	2.20	2.26	2.30	2.36
Lt-duty Trucks (38%)	.12	.12	.12	.13	.13	.13	.14	.14	.14	.15	.15	.15	.16	.16	.17	.17	.17	.18	.18	.19
Cumulative	.12	.24	.36	.49	.63	.75	.89	1.03	1.17	1.32	1.47	1.54	1.57	1.61	1.66	1.69	1.74	1.79	1.82	1.87
Md/Hv-duty Truck (14%)	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.07	.07	.07
Cumulative	.04	.09	.14	.19	.24	.29	.34	.39	.44	.49	.55	.57	.58	.59	.61	.62	.64	.66	.67	.69

^a From Du Pont ESCON model to 1990; thereafter escalated at 2.5% growth in fleet per year

^b Leaded-gasoline burning vehicle sales are estimated to be 20% of total fleet sales (13% of cars, 32% light trucks, 100% medium/heavy trucks).

^c 1987 and beyond, this sales proportion is taken as synonymous with total leaded proportion of gasoline fleet.

^d Sales estimated at 10% of total fleet per year (correlates with 10-yr average life)

^e Accumulative penetration of vehicle sales from 1987-1997; any control option commencing in 1987 is assumed to have realized full effect after 10 yrs (fleet turnover based on 10-yr average life, 10%/yr). Thereafter, equivalent to proportion of fleet (row #2).

TABLE D-2 LEADED VEHICLE FLEET COMPOSITION (1987)

	Passenger Cars	Light Trucks	Medium/ Heavy Trucks	Total
Total Vehicle Sales (ESCON Model) (Vehicles x 10 ⁶)	1.15	0.38	0.04	1.58
% Leaded	13%	32%	100%	20%
Leaded Vehicles (x 10 ⁶)	0.15	0.12	0.04	0.32
% of Total Leaded by Category of Vehicle	48%	38%	14%	100%

cumulative additions of the year-by-year sales numbers. For simplicity, rather than factor in scrappage rates, a 10-year average vehicle life is assumed. Therefore, by the tenth year (1997), the vehicles concerned (for example, new vehicle sales equipped with a lead trap commencing in 1987) are assumed to have fully penetrated their respective portion of the fleet (in this case, leaded gasoline passenger cars).

The "penetration" phase is considered by then to be complete, and thereafter, the fleet numbers are identical to those shown in Table D-1.

Special Excise Tax on Leaded Gasoline

During the initial identification of options to reduce automotive lead emissions, it was suggested by the Economic Council of Canada that special tax or price regulatory measures could be used to achieve these environmental objectives, while at the same time realizing a more efficient allocation of economic resources.

One such measure would be to discourage the use of leaded gasoline by means of an excise tax which could, in theory, be regulated in order to reduce the volume of leaded gasoline sold. Econosult Inc. of Montreal was contracted to determine the feasibility of a strategy to reduce the sales of leaded gasoline in Canada to between 20% and 40% of total gasoline sales by a special excise tax on leaded gasoline (3). The underlying hypothesis is that by making the price of leaded gasoline the same or slightly higher than the price of lead-free gasoline, some consumers will modify their buying behaviour and switch to lead-free. This behaviour modification would result from the removal of the current economic incentive that exists because of the price differential between leaded and lead-free gasoline. Similarly, this would apply not only to owners of leaded gasoline designated vehicles but also to those owning lead-free designated cars who are misfuelling with leaded gasoline.

It should be noted that a precedent already exists for an excise tax differentiated between leaded and lead-free gasoline. There are two federal taxes on gasoline imposed under the Excise Tax Act. The first is a 9% ad

valorem tax on the sales price to retailers which is levied on producers or importers. The second is a special excise tax on gasoline used for personal (vs commercial, farm, etc.) consumption (70).

Summary of Consultant's Findings. Based on a review of relevant price-demand literature, Econosult arrived at the following conclusions:

- from the statistical evidence, the price differential between leaded and lead-free gasoline does not seem to have influenced the consumer's choice between grades or the ratio of lead-free/leaded gasoline sales;
- volumes sold in provinces where the ratio of unleaded to leaded gasoline is highest (i.e., in Quebec and Ontario) and in provinces where the ratio is lowest (i.e., Saskatchewan and Alberta) indicate that the price cross-elasticity of demand between grades may be low or nil;
- if gasoline prices increase sufficiently, the consumer may try to maintain his previous level of consumption and expenditures by converting to a lower-priced grade.

These preliminary conclusions were confirmed by a detailed analysis of price/volume relationships during and after a gasoline price war when costs per litre and price differentials varied considerably and rapidly. Regression analysis confirmed that, without change in other factors, the sales of lead-free gasoline would not increase if the price of leaded gasoline increased. Changes in the price structure of the two grades, it was concluded, do not affect the demand for each grade.

The consultants also concluded that, in view of the divergent price differentials across Canada, a tax to reduce the differential (but not to remove it altogether) could not be the same percentage or the same number of cents per litre across the country. Similarly, a tax imposed separately by each provincial government designed to reduce, but not remove, the price differential would require enabling legislation (insofar as it could not be imposed under existing legislation) and would involve exemptions and complex calculations resulting in significant administrative problems. Notwithstanding the above conclusions, even if such a tax was successful in reducing sales of leaded gasoline, the impact (i.e., price increases) would fall disproportionately on Western Canada.

Furthermore, an examination of the relative merits of an excise tax in terms of its likely effectiveness and efficiency gave rise to the following expectations:

- an excise tax will be passed on to the consumer to the maximum possible extent, dependent on elasticity of demand and competitive activity;
- an excise tax increase will probably be accompanied by an increase in price which will accrue to the distributor;

- it will be difficult if not impossible to isolate the precise effects of a percentage or cents-per-litre tax on the selling prices at the pump of the grades concerned.

Econosult also investigated the use of a direct price regulation of leaded gasoline and concluded that this does not appear to be a feasible means of influencing gasoline grade volumes and shares. If the regulated price is set above the market clearing price, the oil companies would initially make windfall profits, but surpluses of leaded gasoline would develop. To maintain the regulated price at an artificial level it would be necessary for the government to also regulate volumes of output at the various refineries. This would require that the regulators possess much greater knowledge of process technologies and of changing markets than would likely to be the case.

To summarize, the study confirms that in theory an excise tax remains a feasible strategy, provided that means could be found to implement and maintain the excise tax and to regulate the selling prices at the pump at predetermined levels. However, in view of the finding that cross-elasticity between the grades is negligible, it is not expected that an excise tax could be used by the government as an instrument of fine tuning, especially if the price of leaded gasoline remains to any extent lower than the price of unleaded gasoline. Maintaining the pump price of leaded gasoline at or above the price of unleaded gasoline is also subject to serious question.

Basis of Excluding an Excise Tax and/or Regulatory Price Option. While it was felt that it warranted investigation, there are several reasons why excise tax and regulatory price measures are not included in the slate of control options under consideration at this time, namely:

- the findings and conclusions themselves as stated by the consultant;
- investigation of the subject matter has been limited; there are currently (as indicated by the consultant) too many questions and potential problem areas left unaddressed;
- an excise tax and/or regulatory price option was not incorporated within the Control Options Report. Industry and other parties, therefore, did not have the opportunity to assess and comment upon this matter;
- the intent of an excise tax strategy, notwithstanding the problems identified, is to accelerate the decline of leaded gasoline demand. It would increase the probability for such a decline to occur despite a rumoured trend towards increased production by manufacturers of lead-tolerant cars. However, there is no knowledge of the rate at which this accelerated decline would occur;
- the options under consideration, with the exception of the status quo, realize short-term and significant reductions in lead emissions. Moreover, the new-car lead-trap option was modified to include the retrofit of lead traps on existing vehicles, thereby producing these more immediate reductions. An excise tax strategy would not produce comparably quick reductions in emissions;

- even with an accelerated attainment of the grade split (70%/30%) that is projected to materialize under the status quo, the Econosult investigation does not address whether and how far beyond this ratio the accelerated change would carry on. The projected stabilized demand of 30% leaded gasoline includes, it must be remembered, not only passenger car consumption, but also light-duty and medium/heavy-duty commercial truck consumption, as well as misfuelling.
- there would be problems with communicating and rationalizing higher regulated prices to the consumer;
- the consultant indicated that, with the excise tax option, refineries, distributors and retailers would still have the freedom to practice pricing policies which could lead to a reassertion of a price differential;
- finally, there would presumably be a cost attached to the administration of such a program. Such costs have not been identified.

Process of "Moral Suasion". Although not investigated to any great degree and not included as an option under consideration, it is perhaps necessary to briefly mention an approach referred to as "moral suasion". The concept of moral suasion by the government would involve a request to petroleum marketers to equalize the pump prices of leaded and lead-free regular gasolines. Although enabling legislation would perhaps be passed, this would be carried out without regulation; over a fixed period of time, government would refrain from applying any tax measures (70).

The arguments in favour of such an approach are that the goals would be achieved without forcing petroleum markets to pay new, additional taxes and that it would avoid the delays of implementing a new tax system.

The assumption is that the oil companies would equalize the prices of leaded and lead-free at a value which represents a fair equalization of the cost to the consumer of the two previous prices; what this price would be and how it would be arrived at is unknown. Nor is it known to what extent leaded gasoline demand - and therefore emissions - would be reduced.

Regulation of Lead Content in Total Gasoline Pool

Several of the submissions made to the Minister by the petroleum industry advocated an approach based on a lead limit in the total gasoline pool. Present regulations limit the maximum lead content allowable in any litre of leaded gasoline. As stated by Du Pont, "this means that a refiner cannot use any more than this amount in any litre at any time and is unable to average dosage over time or over his total production of gasoline" (67). By definition, a total gasoline "pool" approach to lead content would, for the refiners part, rectify these matters.

At the very least, a pool approach would involve setting a limit for the maximum lead content per litre averaged over total gasoline production (the pool). This obviously would afford considerable leeway to increase concentra-

tions of lead additives in leaded gasoline as the volume of lead-free (and therefore the use of more octane barrels) increases. However, further characteristics of the pool approach could include not only a pool limit, but a limit also on the maximum concentration in leaded gasoline. Other variations proposed include averaging the lead content over time (say quarterly) and the allocation of "unused" lead additives (difference between allowable and what is actually used) between refineries.

Refiners' and lead additives manufacturers' arguments in favour of such an approach rest on considerations that this allows more octane quality from lead additives as increased lead-free processing consumes an increasing number of natural octane barrels. This allows the refiner to produce gasolines of required octane quality with minimum investment and energy penalty.

The limits (or "caps") to the lead content in the total gasoline pool suggested by industry cover a fair range. Table D-3 is intended simply to illustrate the difference between the pool lead level under the status quo of 0.77 g/L and a limit set at 0.68 g/L. The difference, as can be seen, is minimal.

An assessment of the feasibility and practicality of a pool approach, however, would appear to rest on two key considerations:

- firstly, the legality of such an approach. Two schools of thought exist, one claiming that the provisions of the Clean Air Act restrict and pertain to the concentration of lead in leaded gasoline only, the other claiming that the Governor General in Council has additional and as yet unexhausted authority under the Act to set more flexible limits. This is very much a question of legal interpretation, and to attempt to do so is obviously beyond the role of this SEIA;
- secondly, and in the final analysis, the practicality of a pool approach - given that it is, for the sake of argument, possible under the Clean Air Act - must be judged in light of the desired reduction in lead emissions with respect to the benefits to human health.

D.2 ALLOCATIVE COSTS

Refinery Capital and Operating Cost Estimates

Refinery capital and operating costs illustrate the greatest disparity in cost estimates, especially in the case of the lead-free option. Environment Canada (2) has estimated a capital investment of \$43 million (\$1982) whereas PACE (51) states that the impact to the petroleum refinery industry will be in the order of \$1.1 billion (\$1983). A clarification of the assumptions and methodology underlying these estimates is necessary.

Control Options Report Estimates (Environment Canada). The basis for the minimum case estimates presented by Environment Canada was the capital and operating costs generated by MHG International Ltd. (43,48,73,74). A detailed description of the methodology employed by MHG is contained in the consultant's report; a summary description is also to be found in Appendix 1 of the Control Options Report.

TABLE D-3 TOTAL GASOLINE POOL LEAD CONTENT

Year	Leaded Gasoline Sales Forecast (L x 10 ⁹)	Total Gasoline Sales Forecast (L x 10 ⁹)	Total Gasoline Pool Lead Content with Lead Concentration of:	
			0.77 g/L	0.68 g/L ^a
1985	14.8	32.8	0.35	0.31
86	13.7	32.4	0.33	0.29
87	12.6	32.0	0.30	0.26
88	11.4	31.5	0.28	0.25
89	10.3	31.1	0.26	0.23
1990	9.2	30.7	0.23	0.20
91	9.2	30.8	0.23	0.20
92	9.2	30.8	0.23	0.20
93	9.3	30.9	0.23	0.20
94	9.3	30.9	0.23	0.20
1995	9.3	31.0	0.23	0.20
96	9.5	31.5	0.23	0.20
97	9.6	32.0	0.23	0.20
98	9.8	32.5	0.23	0.20
99	9.9	33.0	0.23	0.20
2000	10.1	33.5	0.23	0.21
01	10.1	33.5	0.23	0.21
02	10.1	33.5	0.23	0.21
03	10.1	33.5	0.23	0.21
04	10.1	33.5	0.23	0.21
2005	10.1	33.5	0.23	0.21
06	10.1	33.5	0.23	0.21
07	10.1	33.5	0.23	0.21

^a Maximum lead concentration forecast by ILZRO

MHG's preliminary assessment concluded that cost estimates for each of the 37 Canadian refineries in operation at that time would be impractical because each refinery had a slightly different configuration, crude slate and product slate. As a close approximation, MHG therefore grouped the refineries into four regional composite refineries, each having in total the characteristics of the individual refineries within its region.

A computer simulation model was developed in order to estimate the additional refinery capital and operating (processing and energy requirements) costs necessitated by the reduction of lead levels of regular leaded gasoline to 0.44, 0.22 and 0 g Pb/L.

Later, when reviewing the adjustment to MHG's cost estimates carried out by Environment Canada, it is important to keep in mind that MHG's process simulator was calibrated using 1979 data. This included the total gasoline demand for 1979 which, at the time of the study, was assumed to be roughly the same as the forecast volumes which would be sold in the years 1985-1990. Furthermore, the gasoline grade split used in the model was the ratio of leaded to lead-free gasoline in effect in 1979; the estimated costs for a reduction or elimination of lead in leaded gasoline were based, therefore, on a larger leaded gasoline volume than would be the case at the time of implementation of any possible regulatory action.

While retaining original crude slates, the optimizing criteria used by MHG to forecast costs were:

- maximum utilization of existing process units;
- minimum crude oil consumption; inasmuch as increased crude oil consumption is disadvantageous to the Canadian economy, this was viewed as the key parameter when solving for the optimal case.

At lead concentrations of 0.44 and 0.22 g/L, MHG estimated that no refinery capital investment would be required. However, the consultant did note that:

"this conclusion is hypothetical and does not preclude the possibility of certain refineries requiring process unit capacity created by divergences in refinery process configuration, crude diet, product slate (plus seasonal product demand changes) from the regional Base Case" (48).

The study estimated that incremental process operating costs to meet the 0.44 and 0.22 g/L levels would be approximately \$14.4 and \$49.7 million, respectively.

The cost estimates for a total lead-free gasoline demand were first calculated on an existing marketplace octane level for lead-free regular of 94 RON. The capital investment required if all leaded gasoline in 1979 was converted to regular lead-free gasoline was estimated to be \$886 million (for additional process facilities, including reforming, isomerization, alkylation and desulpherization) while incremental operating costs, including a net energy penalty, were estimated to be \$130 million (71). (In accordance with Treasury Board guidelines, capital carrying charges, insurance costs and taxes have been subtracted.)

Ethyl Canada likewise conducted a study of refinery costs for the high RON case based on discussions with Canadian refiners (72). The estimated capital costs for a lead-free option were \$466 million which included an investment of \$70 million for Eastern Canada and \$396 million for Western Canada. However, no provision was made in the Western Canada analysis for the effect of the lower octane actually required in that region.

The reason for the difference between these two estimates is largely attributable to the fact that MHG projected a requirement for an additional 229,000 barrels per day (bbl/d) reforming capacity, whereas Ethyl estimated a requirement of only 155,000 bbl/d. MHG believed that it would be necessary to scrap existing reformer units and replace them with new units. Ethyl and likewise Environment Canada believe that existing high-pressure reformers could be upgraded and optimized to more efficient low-pressure reformers, thereby reducing the capital investment requirements.

Once-through (or Single) Isomerization at CGSB Specifications (Environment Canada)

MHG also calculated the refinery capital and operating costs that would be required by a total lead-free gasoline slate, not at existing octane levels but at the Canadian General Standards Board (CGSB) product specifications of 92 RON and 87 (R+M)/2 (48). In this scenario, the consultant indicated that it would be necessary to install isomerization facilities (73,000 bbl/d) to produce an additional 25.5 billion litres/year of lead-free gasoline. This would increase total annual lead-free production (1979) from 11.8 to 37.3 billion litres. The estimated capital cost (+ 30% accuracy, \$1979) was \$64 million, while the incremental annual operating cost was estimated to be \$34 million.

Environment Canada has proposed that cost estimates should be based upon these CGSB specifications. The basis for their argument is that:

- canvassing of major Canadian automobile manufacturers by Transport Canada established that octane requirements for 1982 and 1983 automobiles would be 91 RON and 87 (R+M)/2 (49);
- whereas both the U.S. and Canada have historically produced a regular gasoline with 94 RON, the U.S. industry has reduced this to 92.5 RON in the last decade; it is assumed by Environment Canada that the Canadian industry will likewise reduce the octane level to 92 (2);
- CGSB octane specifications for regular gasoline would, therefore, be satisfactory for automobile operation.

In the Control Options report, octane levels were expressed in terms of RON values. More appropriately, the octane levels should be defined as (R+M)/2^a, or antiknock index; (R+M)/2 values produced by the "once-through" isomerization process are (48):

^a (R+M)/2 = Average of Research Octane Number (RON) + Motor Octane Number (MON); otherwise referred to as AKI, or antiknock index.

	<u>(R+M)/2</u>
Atlantic	87.6
Quebec	88.0
Ontario	88.5
Western Canada	87.0

Using the regional breakdown of 1979 motor gasoline volumes used in MHG's study, a sales weighted average of 87.7 (R+M)/2 is derived from the once-through isomerization process (48).

Incorporating information provided by PACE which indicated the historical investment made by the petroleum industry between 1972 and 1980 to produce lead-free gasoline (50), Environment Canada estimated that the Canadian refining industry has the capacity at present to produce 21.8 billion litres/year of lead-free gasoline. This equated to approximately 60% of the total gasoline demand forecast at the time of the Control Options Report (2).

Environment Canada therefore claims that the petroleum industry has prebuilt lead-free production capacity and that it would only be necessary to construct additional facilities to produce the 13.6 billion litres of lead-free gasoline required by 1986 (the regulatory date proposed in the Control Options Report).

Hence, the costs for a complete lead-free gasoline slate proposed by Environment Canada, based on CGSB's octane specifications for regular gasoline of 92 RON Eastern Canada and 90 RON Western Canada, were arrived at by taking a portion of MHG's cost estimates corresponding to the production capacity shortfall (total 1986 gasoline demand less assumed lead-free refining capacity).

1. (1986 total gasoline forecast demand) - (existing lead-free capacity) = shortfall in lead-free production capacity.
2. $\frac{\text{capacity shortfall}}{\text{total leaded gasoline requirements (1979)}} \times \text{MHG cost estimates}$

= required investment or operating costs, 1979.

$$\frac{13.6 \text{ billion litres}}{25.5 \text{ billion litres}} \times \text{MHG \$} = x \a$

The costs calculated were then inflated to 1982 dollars. Based on this formula, Environment Canada estimated that 1982 capital and direct operating costs necessitated by the incremental capacity demand would be \$43 million and \$32 million/year, respectively (2).

^a The equation used by Environment Canada, in imperial measure, was $\frac{3.0 \text{ billion gallons}}{5.55 \text{ billion gallons}} \times \text{MHG cost estimates (2)}$.

Recycle Isomerization (Environment Canada)

Following the publication of the Control Options Report, Environment Canada calculated an additional set of refinery capital and operating costs for the lead-free case based upon a recycle isomerization process. Whereas the minimum case cost estimates discussed above involve a "once-through" isomerization process, the recycle isomerization process recycles the straight, normal paraffinic product stream. This results in a boost in the total stream octane of 13-17 units over the once-through isomerization process (75).

Environment Canada's rationale for generating this additional set of cost estimates rests on two considerations

- a recognition of the significant disparity that exists between the minimum case (all lead-free at CGSB specifications) and industry cost estimates;
- the desire to illustrate the capabilities of recycle isomerization units to achieve higher $(R+M)/2$ values.

The $(R+M)/2$ octane values estimated by Environment Canada are:

Atlantic	- 88.3
Quebec	- 88.7
Ontario	- 89.2
Western	- 90.8

In the minimum, or "once through" isomerization case, Western Canada was not allocated any isomerization capacity. When estimating for recycle isomerization, facilities are assumed to be installed in all four regions, with the result that Western Canada attained a more than adequate and highly refined octane system.

A sales-weighted-average $(R+M)/2$ of 88.9 is calculated using the regional breakdown of gasoline volumes (1979) contained within MHG's study; Western Canada is excluded and this is therefore an octane rating at sea level.

Costs for the recycle isomerization case were based upon the assumption that recycle isomerization capital investment costs would be twice the corresponding costs for a once-through isomerization process^a(76). Using the regional costs provided by MHG, Environment Canada estimated recycle isomerization capital requirements as follows:

	$\$ \times 10^6$ <u>Once-through</u>	<u>Recycle</u>
Atlantic	14.15	28.3
Quebec	18.95	37.9
Ontario	30.5	61.0
Western Canada	-	82.6
	<u>63.6</u>	<u>209.8</u>

^a There is more than one version of recycle isomerization, depending upon the degree of recycle employed. The scenario treated here is regarded by Environment Canada as a "standard" recycle isomerization process (75).

Costs for Western Canada are based on twice the investment costs estimated by MHG for the high RON case.

As in the minimum investment requirements (once-through isomerization) described earlier, Environment Canada assumed that only a shortfall capacity of 13.6 billion litres (3 billion gallons) needed to be provided, rather than the 25.2 billion litres (5.55 billion gallons) upon which MHG's estimates were based. Inflating the 1979 estimates to 1983 dollars and applying the equation described above results in an estimated capital cost of \$150 million (because of inherent assumptions, and for simplicity, the estimate has been rounded to the nearest \$10 million).

The ratio of energy requirements (electricity, fuel and steam) of the recycle to the once-through isomerization process was estimated by Environment Canada to be 1.63. The operating costs provided by MHG for an all lead-free case at CGSB specifications, once inflated to 1983 dollars, were adjusted using this ratio, producing an estimated operating cost of \$59.1 million. Again assuming that only the shortfall capacity of an incremental 13.6 billion litres/year needs to be met, this was recalculated as \$31.9 million. To this was added a maintenance factor equivalent to 4.5% of capital investment, or \$6.8 million. The total annual estimated operating cost, rounded, is therefore \$40 million.

Maximum Case - PACE

As did numerous petroleum companies and other concerned parties, the Petroleum Association for the Conservation of the Canadian Environment (PACE) submitted a brief in response to the Minister's request for advice relative to the Notice of Intent to further regulate the lead concentration in motor gasoline (51).

Recalling that all such submissions were in effect addressing the assumptions and estimates as contained in the Control Options Report, PACE voiced the following concerns:

- current octane levels, expressed in terms of AKI (antiknock index or $(R+M)/2$), are 91.8 premium and 88.7 regular sales weighted averages. Environment Canada has assumed that these are higher than necessary and has based its cost estimates on CGSB specifications, which are minimum values derived from industry/user/government consensus and are designed to protect the consumer;
- whereas many new cars will indeed operate with gasoline at minimum specifications, engine octane requirements increase by 4 to 8 units as the vehicle ages (increased km); this increased octane requirement is more marked in lead-free designated vehicles than in leaded-gasoline designated ones;
- Environment Canada's assumption that Canadian RON will conform with U.S. levels is unrealistic because of the difference in feedstocks used and refinery configurations. The suitable indicator of customer requirements is $(R+M)/2$ rather than RON. If the refiners' normal production gives high

sensitivity gasoline, they must then overblend to meet a given AKI criterion. An RON/AKI criteria of 91/87 is only applicable to a sensitivity value of 8, whereas the current lead-free pool average is 9.5;

- customer dissatisfaction will increase with lower octane lead-free gasoline. The result will be a swing from regular to premium lead-free gasoline, thereby eliminating the implied spare octane capacity and savings achieved by lower performance levels.

Dissatisfaction among motorists (a measurement of the percentage who will perceive engine knock using current octane level gasolines with 89 (R+M)/2), is estimated to be in the order of 20%. With (R+M)/2 reduced to 87, the consensus of industry and associations such as the Canadian Automobile Association (77) and ILZRO (56) is that this would increase to approximately 35%. Again, it is proposed that an increased proportion of motorists would switch to premium lead-free.

PACE requested its member companies to submit individual cost estimates based on the specific requirements of each of their refineries. These estimates are likewise based on the assumption that present-day quality levels would be maintained. The aggregates of these submissions for each of the lead phase-down cases under consideration are presented in Table D-4.

TABLE D-4 INDUSTRY ESTIMATE OF LEAD PHASE-DOWN COSTS (\$ x 10⁶, \$1983)

	g Pb/L		
	0.29	0.15	0
Capital Cost	240	825	1100
Annual Operating Cost - PACE	100	325	450
Annual Operating Cost - less 25% capital, insurance and taxes	40	120	180

It is to be noted that PACE's annual operating costs include the cost of capital, taxes and insurance - costs which Treasury Board regards as transfer costs and which are therefore to be deleted when assessing allocative effects (86). Consequently, the operating costs provided by PACE have been reduced by a value equal to 25% of the corresponding capital investment cost. It is believed that this is a conservative approximation of the value of capital, taxes and insurance costs; it also correlates with values used by MHG and with estimates submitted by the petroleum companies themselves to Environment Canada (75).

Adjustment of PACE Cost Estimates

The assumption is made by Environment Canada that the industry estimates provided by PACE are based on the total additional lead-free production required (the difference between 42% lead-free at present and 100% under the

lead-free option, or 60%), and are not therefore incremental cost estimates. Furthermore, industry estimates do not appear to reflect lead-free capacity pre-built during the 1970s. Environment Canada also remarks that PACE had previously indicated that the MHG high RON lead-free estimates of \$886 million capital costs were more or less acceptable (75).

Given these considerations, the possibility is presented that the PACE estimates are in fact overstated. To reflect this possibility, they have therefore been adjusted in a manner similar to Environment Canada's adjustment of MHG estimates. The factor used is 0.5, representing the ratio of incremental volume after natural phase-down (30%) to the volume share of leaded gasoline at present (60%).

Method of Capital and Operating Cost Presentation

For each of the regulatory control options involving a phase-down of the lead content of leaded gasoline, a range of cost estimates is presented (Tables D-5 to D-7). For the 0.29 and 0.15 g Pb/L options, this provides a comparison of Environment Canada estimates (based upon MHG data as described) and PACE petroleum industry estimates, both total and adjusted. In the zero lead case, a scenario reflecting Environment Canada's estimates of recycle isomerization is added.

In each case it is assumed that a further regulation of lead content, if promulgated, would come into effect in 1987, thus allowing 3 years for development and implementation of the necessary capital programs. The studies conducted by MHG had earlier identified a 4-year lead time due to an apparent shortage, at the time the studies were conducted, of the necessary skilled labour. As a result of the recent economic downturn, cancellation of certain megaprojects and a general softness in the construction trades, it is now assumed that this problem is somewhat alleviated.

Refinery capital costs have been spread over 3 years in progressively larger amounts of 20%, 35% and 45% (1984, 1985 and 1986, respectively). Annual operating costs have been projected outwards for 20 years (1987-2006) based on the proposition that this is the "life" of the facilities installed (78). Operating dollars are held constant in 1983 dollars, the assumption being that all costs (and benefits) will increase in relative proportion to each other. Present values are calculated using a discount factor of 10%.

Alternative Octane Extenders(2)

High-octane compounds, other than refinery-produced products, could be used by refiners to increase the octane number of the gasoline pool. These compounds include MTBE (methyl tertiary butyl ether) and alcohols (methanol or ethanol), and can be used as blending components in proportions up to 15% of the gasoline.

MTBE. Natural gas can be used to produce methanol and isobutylene, which are then reacted to form MTBE. The use of MTBE to boost the octane number of the gasoline pool is increasing rapidly in Europe and the U.S. The RON range of MTBE-blended gasolines is 115-135; the actual blending number generally rises as the gasoline base octane number decreases and saturates content

TABLE D-5 REFINERY INVESTMENT AND OPERATING COSTS
OPTION #2 - 0.29 g/L (\$ x 10⁶)

Year	Percent Capital Allocations	Control Options Report		Industry Est. (PACE) Current Octane Levels		Industry Est. (PACE) Adjusted for Incremental Lead-free Volume	
		Annual	PV	Annual	PV	Annual	PV
1984	20%	4.0	3.6	48	43.6	24	21.8
1985	35%	7.0	5.8	84	69.4	42	34.7
1986	45%	9.0	6.8	108	81.1	54	40.6
1987		15	10.2	40 ^a	27.3	20 ^c	13.7
1988		15	9.3	40	24.8	20	12.4
1989		15	8.5	40	22.6	20	11.3
1990		15	7.7	40	20.5	20	10.3
1991		15	7.0	40	18.7	20	9.3
1992		15	6.4	40	17.0	20	8.5
1993		15	5.8	40	15.4	20	7.7
1994		15	5.3	40	14.0	20	7.0
1995		15	4.8	40	12.8	20	6.4
1996		15	4.4	40	11.6	20	5.8
1997		15	3.9	40	10.5	20	5.3
1998		15	3.6	40	9.6	20	4.8
1999		15	3.3	40	8.7	20	4.4
2000		15	3.0	40	7.9	20	4.0
2001		15	2.7	40	7.2	20	3.6
2002		15	2.5	40	6.6	20	3.3
2003		15	2.2	40	6.0	20	3.0
2004		15	2.0	40	5.4	20	2.7
2005		15	1.8	40	4.9	20	2.5
2006		15	1.7	40	4.5	20	2.2
NPV (1983)		-	112.3	-	450.1	-	225.3

- ^a PACE operating cost (100) less 25% of capital costs (0.25 x 240) = 40
^b Incremental volume portion (estimated) of industry capital cost projection (0.5 x 240)
^c Incremental volume portion (estimated) of industry operating cost projection (100 x 0.5) - (0.25 x 120) = 20

TABLE D-6 REFINERY INVESTMENT AND OPERATING COSTS
OPTION #3 - 0.15 g/L (\$ x 10⁶)

Year	Percent Capital Allocation	Control Options Report		Industry Est. (PACE) Current Octane Levels		Industry Est. (PACE) Adjusted for Incremental Lead-free Volume	
		Annual	PV	Annual	PV	Annual	PV
1984	20%	6	5.5	165	150.0	83	75.4
1985	35%	10	8.3	290	239.5	145	119.8
1986	45%	14	10.5	370	277.9	187	140.3
1987		25	17.1	120 ^a	82.0	60 ^c	41.0
1988		25	15.5	120	74.5	60	37.3
1989		25	14.1	120	67.7	60	33.8
1990		25	12.8	120	61.6	60	30.8
1991		25	11.7	120	56.0	60	28.0
1992		25	10.6	120	50.9	60	25.4
1993		25	9.7	120	46.3	60	23.2
1994		25	8.8	120	42.0	60	21.0
1995		25	8.0	120	38.3	60	19.1
1996		25	7.3	120	34.8	60	17.4
1997		25	6.6	120	31.6	60	15.8
1998		25	6.0	120	28.7	60	14.3
1999		25	5.5	120	26.2	60	13.1
2000		25	5.0	120	23.8	60	11.9
2001		25	4.5	120	21.6	60	10.8
2002		25	4.1	120	19.7	60	9.8
2003		25	3.7	120	17.9	60	8.9
2004		25	3.4	120	16.2	60	8.1
2005		25	3.1	120	14.8	60	7.4
2006		25	2.8	120	13.4	60	6.7
NPV (1983)		-	184.6	-	1435.4	-	719.3

- a PACE operating cost (325) less 25% capital costs (0.25 x 825) = 120
b Incremental volume portion (estimated) of industry capital cost projection (0.5 x 825)
c Incremental volume portion (estimated) of industry operating cost projection (325 x 0.5) - (0.25 x 415) = 60

TABLE D-7 REFINERY INVESTMENT AND OPERATING COSTS
OPTIONS # 4 AND 5 - LEAD-FREE AND LEAD-FREE EXCEPT FOR 0.15 g/L HEAVY TRUCKS (\$ x 10⁶)

Year	Percent Capital Allocation	Control Options Report		Recycle Isomerization		Industry Est. (PACE) Current Octane Levels		Industry Est. (PACE) Adjusted for Incremental Lead-free Volume	
		Annual	PV	Annual	PV	Annual	PV	Annual	PV
1984	20%	9.2	8.4	30	27.3	220	200.0	110	100.0
1985	35%	16.1	13.3	52.5	43.4	385	318.0	192	158.6
1986	45%	20.7	15.5	67.5	50.7	495	371.7	248	186.2
1987		34	23.2	40	27.3	180 ^a	122.9	90 ^c	61.5
1988		34	21.1	40	24.8	180	111.8	90	55.9
1989		34	19.2	40	22.6	180	101.5	90	50.8
1990		34	17.4	40	20.5	180	92.3	90	46.2
1991		34	15.9	40	18.7	180	84.1	90	42.0
1992		34	14.4	40	17.0	180	76.3	90	38.2
1993		34	13.1	40	15.4	180	69.5	90	34.7
1994		34	11.9	40	14.0	180	63.0	90	31.5
1995		34	10.8	40	12.8	180	57.4	90	28.7
1996		34	9.9	40	11.6	180	52.2	90	26.1
1997		34	8.9	40	10.5	180	47.3	90	23.7
1998		34	8.1	40	9.6	180	43.0	90	21.5
1999		34	7.4	40	8.7	180	39.2	90	19.6
2000		34	6.7	40	7.9	180	35.6	90	17.8
2001		34	6.1	40	7.2	180	32.4	90	16.2
2002		34	5.6	40	6.6	180	29.5	90	14.8
2003		34	5.1	40	6.0	180	26.8	90	13.4
2004		34	4.6	40	5.4	180	24.3	90	12.2
2005		34	4.2	40	4.9	180	22.1	90	11.1
2006		34	3.8	40	4.5	180	20.2	90	10.1
NPV (1983)		-	254.6	-	377.4	-	2041.1	-	1020.8

^a PACE operating cost (450) less 25% capital costs (0.25 x 1,100) = 180

^b Incremental volume portion (estimated) of industry capital cost projection (0.5 x 1,100)

^c Incremental volume portion (estimated) of industry operating cost projection, (450 x 0.5) - (0.25 x 550) = 90

increases. MTBE has a low boiling point (55°C); its addition improves the octane number of the high volatile component of gasoline. In engine performance, MTBE-blended gasolines compared with refinery gasolines show no difference in gasoline consumption or horsepower, marked improvement in road octane number at low speed, no difference in evaporation losses, and no problems with icing or corrosion.

Alcohols. Methanol can be produced from natural gas and ethanol from grains. Celanese Ltd. is constructing the largest methanol plant in the world in Edmonton, Alberta. When this plant is completed, a portion of its production will be sold to firm markets but there should be sufficient uncommitted methanol to satisfy the demand for the Canadian gasoline pool.

Methanol and ethanol are both very satisfactory fuels for internal combustion engines. The RON rating of methanol is 112 and that of ethanol is 110. Combustion of these alcohols in automobiles results in low emissions. One disadvantage is that the energy content of alcohols is lower than that of gasoline. Thus, for a given travel radius, a methanol fuel tank has to be 65% larger than that for gasoline. Problems with methanol gasoline blends include difficult cold-weather starting and the separation of methanol from gasoline in the presence of water. These latter problems seem to have been overcome by adding 4-5% methanol with a 4-5% cosolvent such as a heavy alcohol.

In general, these high-octane compounds are better named gasoline extenders rather than additives. As such, the use of these extenders would support the aims of the National Energy Program to reduce crude oil imports and also to convert to natural gas use.

LEAD TRAPS

The lead trap option is a policy option that would require the promulgation, under the Motor Vehicle Safety Act, of a regulation requiring the installation of lead traps on vehicles that are designed to run on leaded fuel. As the terminology implies, the lead trap decreases the exhaust emissions of lead particles from leaded fuel combustion.

As is the case with the other lead phase-down options being considered, various opinions have been expressed as to what the technology involves, how the option should be approached and, subsequently, what the allocative cost impact would be.

Consultant's Study

Pilorusso Research Associates Inc. were commissioned to determine the incremental costs and benefits to Canadians of replacing conventional automotive muffler systems with lead traps on those new vehicles designed to run on leaded fuel (54).

Forecasts were made of the gasoline-burning automobile and light truck fleet through to 1995. Medium-and heavy-duty trucks were ignored, based on the assumption that the trend to dieselization will continue and that virtually all sales in that group would be diesel-powered by 1985. Forecasts of the percentage of Canadian automobile and light truck sales each year designed

to run on leaded fuel were arrived at by analysis of specific model lines and manufacturer share forecasts. These forecasts assumed that if there is a regulation requiring the use of lead traps, the original equipment manufacturers would continue to provide vehicles to run on leaded fuels.

In the Pilorusso study, the lead trap was assumed to be made of stainless steel and, therefore, to be a lifetime system. In order to determine the incremental costs and/or benefits to the Canadian consumer of lead trap systems, comparisons of the lifetime cost of lead traps with both galvanized steel and stainless steel conventional muffler systems were carried out.

Inasmuch as stainless steel lead traps are lifetime systems, they do not require replacement. Conventional muffler systems, however, are replaced an average of 1.47 times over the life of the vehicle. Based on this comparison, the consultant concluded that the incremental cost to the consumer is actually negative; the lead trap would represent a cost saving over the conventional galvanized steel muffler system. For the two designs of lead trap systems considered (Design 1 - agglomerator and cyclone separator and Design 2 - cyclone separator), Pilorosso calculated net present values of savings to Canadian consumers over the period 1986-1995 of \$50 million and \$109 million, respectively.

Similarly, when comparing the costs of a stainless steel lead trap system with a stainless steel conventional muffler system, both are assumed to be lifetime systems with no requirement for replacement. In this instance, there is an incremental cost to the Canadian consumer representing the differential cost of a lead trap vs a conventional muffler. For the two designs treated, the costs estimated (1986-1995) were \$89 million and \$13 million, respectively.

Control Options Report Estimates

The key differences between the Pilorusso study and Environment Canada's Control Options Report (2) are:

- a cost comparison by Environment Canada based on a galvanized (not stainless) steel lead trap vs galvanized conventional muffler. Environment Canada argues that if a stainless steel lead trap is used in the analysis, then the comparison should be with a stainless steel conventional muffler (75). However, just as no one has produced a lead trap for commercial use, nor are stainless steel mufflers installed on current vehicles as lifetime systems. If there are lifetime benefits, then why have they not been installed by the manufacturers? The more realistic comparison, they conclude, is of systems of the same material construction (i.e., galvanized vs galvanized);
- therefore, the lead trap system is not a lifetime system, and would have to be replaced at a frequency similar to conventional mufflers. The cost difference would be the incremental cost of a lead trap over a conventional muffler; the incremental costs (included in the retail price of the vehicle) were estimated to be (2):

- passenger cars - \$50
- light/medium trucks - \$75
- heavy trucks - \$100

- the inclusion within the calculations of medium/heavy-duty trucks.

The net present value (\$1982) of incremental costs to consumers for the years 1986-2000 resulting from a regulation requiring lead traps on new vehicles was calculated by Environment Canada to be \$288 million.

Updated Cost Calculations

For the purpose of this analysis, the same position is taken with regard to the comparison of galvanized lead trap vs galvanized conventional muffler system as was used in the Control Options Report.

However, discussions with Environment Canada subsequent to that report lead to the conclusion that the analysis of the costs and benefits (emissions reductions) is more appropriately based upon installation of lead traps on new vehicles and retrofit on existing leaded-gasoline vehicles (75). A regulation pertaining only to new vehicle sales would result in reductions of lead emissions which increase cumulatively as these new lead-tolerant vehicles - equipped with lead traps - enter the fleet. Based on the assumption of an average vehicle life of 10 years, the full benefit of reduced emissions would not be achieved until 10 years after manufacturers first install lead traps on new vehicles.

In addition, the other options under consideration involve reductions in the lead concentration in leaded gasoline which take effect as of the regulatory date and which realize an immediate reduction in lead emissions. To achieve this same immediacy of emissions reductions, installation of lead traps on new vehicles as well as retrofit on existing vehicle is required. For the sake of comparison, however, the costs are shown for both new vehicle installation and retrofit, and for new vehicle installation alone.

When estimating the differential costs to consumers of lead traps on new vehicles, it is assumed that vehicles equipped with lead traps would first appear in 1987. The methodology used in estimating the "new vehicle" scenario is described below:

Vehicle Sales:

As calculated and shown in Appendix D.1.

Lead Trap Differential Costs - New Vehicle Installation:

The differential cost of lead traps over conventional mufflers used in this analysis are those presented in the Control Options Report (\$50, \$75 and \$100 for passenger cars and light-duty trucks and heavy-duty trucks). It is to be emphasized that these are estimates only in the absence of experience based on commercial production of lead traps.

Lead Trap Differential Costs - Replacement:

Lead traps manufactured from galvanized steel will, as with conventional mufflers, deteriorate through the average life of the vehicle. The replacement frequency for conventional mufflers was previously stated as 1.47 (54). This means, for example, that some vehicles have their muffler replaced twice during the vehicles average lifetime, and others only once. For simplification, the calculations are based on the assumption that all vehicles would have the lead trap replaced after 5 years at a cost of 1.5 (1.47 rounded) times the initial cost differential of a lead trap over that of a conventional muffler. It is recognized that this is at best an approximation of the cost differential, frequency, and timing of the replacement of lead traps.

The calculations for this approach are presented in Table D-8. The net present value of the differential cost of lead traps on new vehicles and the replacement cost, 1987-2006, is \$261.4 million (1983 dollars).

When estimating the cost of retrofitting existing leaded gasoline designated vehicles with lead traps, the following approach is taken:

Breakdown of Leaded Vehicle Population

Using Du Pont ESCON data, it is estimated that in 1985/86, 20% of existing passenger cars, 32% of light-duty trucks, and 100% of medium- and heavy-duty trucks would be using leaded fuel (57).

Timing of Retrofit:

With a regulatory date of 1987, it is arbitrarily assumed that the retrofit of lead traps would be spread evenly over 1985 and 1986. This may be debatable, depending on the lead time to develop suitable lead traps for the numerous leaded gasoline car models currently on the road.

Retrofit Cost:

Insofar as it is difficult to estimate the cost of a lead trap installed on a new vehicle by the manufacturer, it is likewise difficult to estimate the cost of a retrofit lead trap "on the street". A review of Pilonusso's data and retail costs indicates that the cost of a conventional muffler is at least twice the factory-installed value to the manufacturer. It is likewise speculated that the cost to retrofit a lead trap would be twice the estimated new vehicle installation cost. This value may be regarded as a differential cost, for the retrofit of an existing leaded vehicle would, for many, take the place of the normal replacement of a deteriorated conventional muffler system. Again, this is a rough approximation, but one which is felt adequate for the purposes of estimating the order-of-magnitude costs resulting from a retrofit regulation.

The net present value of the cost to the Canadian consumers of retrofitting existing leaded-fuel vehicles in 1985 and 1986 is estimated to be \$375 million (\$1983) (refer to Table D-9).

TABLE D-8 LEAD TRAP OPTION #6 - NEW VEHICLE DIFFERENTIAL AND REPLACEMENT COSTS (Vehicles x 10⁶ and \$ x 10⁶)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
LEADED GASOLINE VEHICLES SALES	0.32	0.32	0.33	0.33	0.34	0.35	0.36	3.7	3.8	0.39	0.39	0.40	0.41	0.42	0.44	0.45	0.46	0.47	0.48	0.49
PASSENGER CARS	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.18	1.8	0.19	0.19	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.23	0.24
- Installed Cost	7.5	8.0	8.0	8.0	8.0	8.5	8.5	9.0	9.0	9.5	9.5	9.5	10.0	10.0	10.5	10.5	11.0	11.5	11.5	12.0
- @ \$50.00	-	-	-	-	-	11.25	12.0	12.0	12.0	12.0	12.75	12.75	13.5	13.5	14.25	14.25	14.25	15.0	15.0	15.75
- Replacement Cost ^a	7.5	8.0	8.0	8.0	8.0	19.95	20.5	21.0	21.0	21.5	22.25	22.25	23.5	23.5	24.75	24.75	25.25	26.5	26.5	27.75
- Total Cost																				
LIGHT DUTY TRUCKS	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.19
- Installed Cost	9.0	9.0	9.0	9.75	9.75	9.75	10.5	10.5	10.5	11.25	11.25	11.25	12.0	12.0	12.75	12.75	12.75	13.5	13.5	14.25
- @ \$75.00	-	-	-	-	-	13.20	13.20	13.20	14.3	14.3	14.3	15.4	15.4	15.4	16.5	16.5	16.5	17.6	17.6	18.7
- Replacement Cost ^a	9.00	9.00	9.00	9.75	9.75	22.95	23.70	23.70	24.8	25.55	25.55	26.65	27.4	27.4	29.25	29.25	29.25	31.30	31.30	32.95
- Total Cost																				
MEDIUM/HEAVY TRUCKS	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
- Installed Cost	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0	7.0
- @ \$100.00	-	-	-	-	-	6.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	9.0	9.0	9.0	9.0	9.0
- Replacement Cost ^a	4.0	5.0	5.0	5.0	5.0	11.0	12.5	12.5	12.5	12.5	13.5	13.5	13.5	13.5	13.5	15.0	15.0	16.0	16.0	16.0
- Total Cost																				
TOTAL COST																				
ALL VEHICLES (Grand Total = 1077.9)	20.5	22.0	22.0	22.75	22.75	53.7	56.7	57.2	58.3	59.55	61.3	62.4	64.4	64.4	67.5	69.0	69.5	73.6	73.6	76.7
PRESENT VALUE ^b (NPV = \$282 (1983))	14.00	13.66	12.42	11.67	10.61	22.77	21.86	20.05	18.58	17.25	16.14	14.94	14.02	12.74	12.14	11.28	10.33	9.95	9.04	8.57

a Replacement cost assumed to occur in fifth year of operation. Replacement frequency (1.47) x initial cost used as approximation of replacement cost.
b 10% discount factor.

TABLE D-9 LEAD TRAP, OPTION #6, COST OF RETROFIT FOR EXISTING VEHICLES

	Year	
	1985	1986
1. TOTAL GASOLINE VEHICLE POPULATION ($\times 10^6$)		
Passenger Cars	11.4	-
Light-duty Trucks	3.5	-
Medium/Heavy-duty Trucks	0.39	-
2. LEADED PORTION OF FLEET ($\times 10^6$)		
Passenger = 20% of total fleet ^a	2.28	-
Light-duty Trucks = 32%	1.12	-
Medium/Heavy-duty Trucks = 100%	0.39	-
3. RETROFIT PROGRAM TIMING (2 years)		
Passenger Cars	1.14	1.14
Light-duty Trucks	0.56	0.56
Medium/Heavy-duty Trucks	0.20	0.20
4. RETROFIT COST (\$ $\times 10^6$)		
Passenger @ \$100 per vehicle	114	114
Light-duty Trucks @ \$150	84	84
Medium/Heavy-duty Trucks @ \$200	40	40
	<u>238</u>	<u>238</u>
5. PV \$1983	196.6	178.7
NPV OF RETROFIT (1983) \$375.3 million		

^a Leaded-fuel designated passenger cars (existing) portion at 20% is based on Du Pont ESCON model fuel-consumption and is somewhat higher than the 13% projected new sales portion but, conversely, probably lower than actual percentage of fleet at this time. Total costs would therefore be higher still.

Concerns with Lead Trap Option

There are many questions pertaining to the costs of lead traps, means of implementing and ensuring compliance to the program, the effectiveness of lead trap technology, disposal of discarded lead traps, and other considerations.

Costs: As indicated above, the costs of factory-installed and retrofit systems are, in the absence of commercially produced lead traps, at best, estimates. The development and production of lead traps would have to take into account the variety of vehicle underbodies and other design (e.g., engine) factors, and therefore the number of different lead trap designs that would be required to accommodate these variations. Concern has also been expressed that the floorpan configuration and design of some existing small passenger cars would not accommodate a lead trap (which may be larger than the conventional mufflers with which such cars are fitted). EMR have apparently proposed that a heat exchanger may be required in order to reduce exhaust gas temperature, thereby permitting the lead trap to realize its full "collection" capability (75).

Implementation of Retrofit Program: No attempt is made to determine how the retrofit program would be carried out and what effect, if any, this would have on costs. Retrofitting could be handled by any or all existing retail muffler outlets, by outlets designated/certified by the regulatory body, or by government-run establishments. In the first two cases, there would conceivably be additional costs incurred by the retail market in handling the large number of vehicles (3,800,000) affected; these would presumably be passed onto the consumer as part of the retrofit price. Similarly, setting up and operating government-run installations would incur costs which have not at this stage been estimated. Total per-unit lead trap costs, therefore, are at best rough estimates.

Compliance Program: No costs are included for a compliance and monitoring Program.

Effectiveness in Reducing Emissions: Estimates vary as to the effectiveness of the lead trap system. Although emissions with a lead trap are estimated to be 25% of the lead content of exhaust gases (vs 75% with a conventional muffler system), certain considerations need mentioning. As the vehicle ages, it is believed that the lead trap becomes "clogged" with lead particles and its effectiveness in trapping lead emissions deteriorates, thereby allowing greater emissions to the atmosphere (1).

Secondly, the 25% of lead particles which, under optimum conditions, still escape to the atmosphere are of the smaller particulate size. Being smaller, they have a longer residence time in the atmosphere and would perhaps contribute to more human exposure than the ratio of capture and emissions would suggest.

Disposal: A system to dispose of the lead contained within discarded lead traps would be required in order to eliminate any potential health hazard from the high concentration of lead within those traps and from the contamination of scrap metal stored by the vehicle scrap yard.

A feasibility study conducted in the U.S. has indicated that it would be possible to collect and recycle the lead (55). An economic and technical feasibility study would, however, be required for the Canadian market.

In the absence of a recycling program, a program of collection and disposal would be required, as well as training programs and standards for those handling the potentially harmful materials. The viability of such a program is debatable in light of existing means and facilities for scrapping vehicles.

Reaction of Automobile Manufacturers: With the enactment of a regulation requiring lead traps on new lead-burning vehicles, the question is raised whether automobile manufacturers would convert a proportion of their vehicle models to lead-free/catalytic converter equipped in order to increase compatibility with the U.S. market, rather than develop a further specialized product line. No attempt, however, has been made to quantify the possible effects on costs of such a trend.

LEAD ADDITIVES MANUFACTURERS

Under the status quo, the demand for leaded gasoline will decline, resulting in a corresponding decline in the demand for lead additives. Regulatory options which result in a reduction of the allowable concentration of lead additives in gasoline will further reduce this demand and will therefore have an impact upon the two lead additives plants owned by Du Pont and Ethyl.

Of interest in this section are the allocative costs which would arise from the closure of one or both of the plants. Other considerations (for instance, loss of jobs) are treated in the section dealing with the non-allocative effects.

In a study carried out by MHG International Ltd., it was observed that without any regulatory action (i.e., maintenance of the status quo) consumption of lead additives is expected to drop to about half the 1979 level by the early 1990s (53). The two Ontario-based manufacturers - Ethyl Canada at Sarnia and Du Pont Canada at Maitland - have a combined equivalent lead capacity of approximately 18,200 tonnes (Ethyl, 10,900 tonnes; Du Pont, 7300). In 1982, they were operating at 53% of combined capacity according to a submission by the International Lead and Zinc Research Organization (ILZRO) (56). Recalculating the demand for a lead additive concentration of 0.77 g/L indicates that this combined capacity would drop to as low as 39% by 1990, and then experience a minor increase to 43% due to the projected upturn in the gasoline forecast described earlier.

Decommissioning of Lead Facilities

When lead additives facilities are shut down, they may either be mothballed or decommissioned. MHG argue, however, that mothballing such facilities would generate security, property tax, and liability insurance costs sufficiently high that the probable decision would be to decommission and dismantle the lead-contaminated facilities. Due to toxic and explosion hazards, decommissioning must be carried out with strict adherence to special safety procedures.

Other facilities which will be affected are the estimated 120 railway tank cars dedicated to the transportation of lead additives, as well as dedicated lead additives storage and handling facilities at each refinery.

Based on the foregoing and the capacity levels shown in Table D-10, the following assumptions are made:

Status Quo - Option 1: With a maintenance of the status quo (under which the demand for lead additives would be the same as Option 6), the demand will be 39% of capacity by 1990. Although either plant could handle this level of additive production, it is suggested (in line with MHG's study) that both plants would remain in operation, albeit at reduced revenues.

0.29 g/L - Option 2: Demand declines to approximately 15% of capacity by 1990. It is suggested that one of the two plants would close. Although MHG speculated that Du Pont would be the first to close, this may be open to question. However, the costs of decommissioning the Du Pont facilities will be chosen in this instance, simply because they are the lesser of the two sets of costs estimated by MHG. These costs were estimated to be \$2.1 million (\$1979). In 1983 dollars, and assuming that the closure and decommissioning takes place in 1987, the net present value is \$2.1 million.

0.15 g/L - Option 3: By 1990, demand would drop to approximately 8% of capacity. As in Option 2, the closure of Du Pont is assumed, with the decommissioning cost identified above (NPV \$2.1 million). Conversely, at a projected capacity level of 10%, ILZRO contend that both plants would close and that the additive requirement "would have to be imported at a cost of possibly \$25 million/year" (56).

Lead-free - Option 4: It is assumed that both plants would close and, furthermore, that the dedicated railway tank cars and refinery facilities would likewise be decommissioned and dismantled. MHG estimated that the cost (\$1979) of decommissioning both plants would be \$5.0 million, of tank cars, \$.4 million (120 @ \$3500) and of refinery facilities, \$1.1 million (37 @ \$30,000), for a total of \$6.5 million. Allowing for inflation, the estimated cost would be \$9.6 million. With probable expenditure in 1987, the NPV is \$6.6 million.

Lead-free Except for 0.15 g/L for Heavy Trucks - Option 5: Estimated demand would be approximately 1% of combined plant capacity, and this would probably be met by imports. All costs as noted in Option 4 would be incurred, with the possible exception of some portion of the cost of

TABLE D-10 LEAD ADDITIVE DEMAND (expressed as Pb) AS PERCENTAGE OF MANUFACTURERS' PLANT CAPACITY

Year	Leaded Gasoline Sales $\times 10^9$	Option 1		Option 2		Option 3		Option 5	
		Status Quo Additive Demand (t of Pb)	0.77g/L ^a Capacity (%)	0.29 g/L Additive Demand (t of Pb)	Capacity (%)	0.15 g/L Additive Demand (t of Pb)	Capacity (%)	Lead-free with 0.15 g/L for Heavy-Duty Trucks Additive Demand (t of Pb)	Capacity (%)
1987	12.6	9.5	53	3.6	20	1.8	10	0.3	1.6
1990	9.2	7.2	39	2.7	15	1.4	8	0.2	1.3
1995	9.3	7.2	39	2.7	15	1.4	8	0.2	1.3
2000	10.1	7.7	43	2.9	16	1.4	8	0.2	1.3
2005	10.1	7.7	43	2.9	16	1.4	8	0.2	1.3

^a Status Quo Option 1 and Lead Trap Option Option 6 would be the same in terms of additive demand.

refinery lead additive facility decommissioning (it is probable that supply arrangements would be made whereby only certain refineries would continue to blend the greatly reduced volume of leaded gasoline required.)

VALVE WEAR IN HEAVY-DUTY GASOLINE-FUELED TRUCKS

General Motors of Canada have voiced concern about the effect that the removal of lead could have upon the gasoline-fueled engines of heavy-duty (20,000 lbs. GVW and heavier) trucks, which they state will give rise to accelerated valve seat deterioration, with subsequent loss of engine performance and an increased frequency of related engine repairs (79). This situation, it is believed, would be aggravated by using a gasoline of less than 89 (R+M)/2 as has been proposed by Environment Canada.

By way of example, GM have indicated that the cost to replace both cylinder heads on a 366 cubic inch gasoline truck engine (because of valve seat wear) would cost approximately \$1200, exclusive of labour and downtime costs. Furthermore, it was indicated that the replacement parts would not be suitable for lead-free fuel inasmuch as the valve seats would again deteriorate in time. A more suitable replacement cylinder head would be one with induction-hardened valve seat surfaces similar to those found in cars; these, however, have not as yet been designed and engineered for the heavy-duty gasoline-powered truck engines in question.

Conversely, according to Environment Canada, Ford have advised that their heavy-duty trucks can run on lead-free gasoline (75). Such being the case, it then sheds doubt on whether a problem would arise and what the magnitude of this problem would be. In other words, given that a problem would be created, at what rate would valve seat deterioration occur and what replacement would be needed in comparison to otherwise normal deterioration and maintenance experienced with current leaded gasoline.

Even if deleterious effects upon valve seats arising from the removal of lead are a non-issue, this does not resolve the question of whether noticeable problems will arise by burning a gasoline having an octane rating less than the rating specified by GM. The average (R+M)/2 rating derived from Environment Canada's minimum refinery cost scenario is 87.7, compared to GM's rating of 89. Given a less than satisfactory octane rating, it has been suggested by industry that there would be a tendency to switch to premium lead-free gasoline at a higher cost to the truck operator (51,56,77,79).

Due to the difficulty of determining the size of the particular portion of the truck fleet in question (gasoline-burning vehicles of the upper Class 6 and of the Class 7 range; i.e., in excess of 20,000 lbs. GVW) and the uncertainty surrounding the suspected problems, no attempt has been made to quantify the impact and costs of the above.

In terms of new trucks in this category, certain factors will probably mitigate the otherwise possible negative impacts, including:

- the existing trend to dieselization;

- an acceleration of this trend as a result of more stringent exhaust emission standards in the U.S. (set for 1985) and the possibility that that heavy-duty trucks in Canada might be further regulated. It is speculated that the effect of the first situation - and more so if both occurred - would be that manufacturers would tend to opt for diesel engines rather than catalyst technology;
- the design, engineering and installation of parts of suitable composition for the remainder of heavy-duty truck gasoline engines.

For the unidentified number of existing heavy-duty gasoline-fueled trucks of 20,000 lbs. GVW or more, two possible solutions exist:

- the development of suitable cylinder heads having valve seats comprised of appropriately hardened metals. Replacement of existing cylinder heads - when required - with such parts would presumably alleviate the problem of accelerated deterioration;
- alternatively, allow the use of gasoline with 0.15 g Pb/L as proposed under Option 5, only by heavy trucks. Furthermore, a variation could be drawn from Option 5 which targets only the heavy-duty trucks in question and which sets an appropriate changeover time for those vehicles sold as leaded-gasoline designated prior to the regulation.

For those vehicles sold prior to 1987 and designed to run on leaded gasoline, a changeover time allowance could be identified during which such vehicles would still be able to obtain leaded gasoline of 0.15 g Pb/L. The changeover time could run to the year 2000, thus accommodating the 12+ years average life of heavy-duty trucks.

D.3 ALLOCATIVE BENEFITS

REDUCTION OF AUTOMOTIVE LEAD EMISSIONS

Estimates of automotive lead emissions that will occur with a maintenance of the status quo (Option 1) and with each of the lead phase-down options under consideration are shown in Table D-11. Status quo emissions, as discussed elsewhere, assume a maximum allowable lead concentration of 0.77 g/L.

Emissions calculations are premised upon an emission factor of 75% of the lead contained in gasoline. The exception is the use of a lead trap (Option 6) which allows only 25% of the lead in gasoline to be emitted to the environment. For purposes of comparison, emissions under Option 6 are in two scenarios: a) lead traps on new vehicles only, and b) lead traps installed on both new and existing vehicles (retrofit) which is the intent of the option. As is apparent, the former results in a minor initial decrease, followed by a progressive decline as new leaded vehicles equipped with lead traps penetrate the fleet.

Under Option 5, it is proposed that gasoline would be lead-free with the exception of heavy-duty trucks which would have access to and burn gasoline with a lead content of 0.15 g/L in order to avoid suspected valve wear problems. The estimated emissions under this option are based on the volumes pre-

TABLE D-11 ESTIMATED AUTOMOTIVE LEAD EMISSIONS 1987 to 2006 (t/yr)

Year	Forecast Leaded Gasoline Sales (L x 10 ⁹)	CONTROL OPTION					#6 Lead Trap (a) New Vehicles Only	New & Retrofit
		#1	#2	#3	#4	#5		
0.77 g/L	0.29 g/L	0.15 g/L	0 g/L	0.15 g/L (Heavy Trucks Only)				
1987	12.6	7300	2700	1400	0	230	6700	2400
88	11.4	6600	2500	1300	0	210	5800	2200
89	10.3	6000	2200	1200	0	190	4800	2000
1990	9.2	5300	2000	1000	0	170	3800	1800
91	9.2	5300	2000	1000	0	170	3600	1800
92	9.2	5300	2000	1000	0	170	3300	1800
93	9.3	5400	2000	1000	0	170	3000	1800
94	9.3	5400	2000	1000	0	170	2600	1800
1995	9.3	5400	2000	1100	0	170	2400	1800
96	9.5	5500	2100	1100	0	170	2200	1800
97	9.6	5600	2100	1100	0	170	2100	1900
98	9.8	5700	2100	1100	0	180	1900	1900
99	9.9	5700	2200	1100	0	180	1900	1900
2000	10.1	5800	2200	1100	0	180	1900	1900
01	10.1	5800	2200	1100	0	180	1900	1900
02	10.1	5800	2200	1100	0	180	1900	1900
03	10.1	5800	2200	1100	0	180	1900	1900
04	10.1	5800	2200	1100	0	180	1900	1900
2005	10.1	5800	2200	1100	0	180	1900	1900
06	10.1	5800	2200	1100	0	180	1900	1900
Total Leaded Gasoline Sales 199.3								
Total Lead Emissions		115,100	43,300	22,100	0	3,610	57,400	38,200

sented in Table C-3 for medium/heavy-duty trucks. The projected volumes, therefore, correspond to a larger number of trucks than the heavy trucks of concern, and the emissions are therefore overstated.

FUEL ECONOMY SAVINGS WITH LEAD-FREE GASOLINE

Significant debate has ensued as to whether in fact any fuel economy benefits are realized as a result of the conversion of leaded-gasoline designated automobiles to lead-free usage and, if so, the percentage and monetary value of the fuel savings realized.

Estimates of Fuel Economy Benefits. Several attempts have been made to resolve this question, including consultant studies commissioned by Environment Canada, other independent studies, and investigation carried out internally within Environment Canada. The result has been fuel economy estimates which range from 0% to 4%.

Current new car sales designated as using leaded gasoline are generally lighter weight cars with smaller engines. Manufacturers are able to tune these engines such that they meet existing Canadian emission standards without a catalytic converter and, therefore, without being required to use lead-free gasoline. Coincident with this, a marketing strategy is afforded which is designed to appeal to the consumer because the cars in question use less expensive leaded gasoline.

With the elimination of leaded gasoline, all vehicles will become lead-free users. For those cars which ran previously on leaded fuel, automobile manufacturers are faced with the choice of producing and marketing these cars with or without a catalytic converter. Assuming that they will be influenced by the consumers' desire for fuel-efficient vehicles, it is assumed that in the majority of cases they will opt for catalyst control technology on the previously leaded-gasoline designated cars. This provides the manufacturers with more standardized (and perhaps less expensive) production and permits them to produce vehicles whose emissions are controlled by the catalytic converter, thereby allowing them to tune the engine for optimum fuel efficiency.

A study conducted by Hickling Partners Inc. (HPI) compared otherwise identical pairs of Canadian vehicles, one lead-free, the other leaded, and showed that when the engine is larger than 3.1 litres and was designed more than 4 years ago, the lead-free vehicles had significantly lower fuel consumption than their leaded "twins" (80).

A more recent study conducted by HPI, entitled "Automotive Fuel Consumption Analysis - U.S. vs Canada", indicates that 1983 U.S. automobiles burning lead-free fuel and using 3-way catalysts (and usually closed-loop controls) achieve more efficient fuel consumption than their Canadian "twins" using leaded gasoline (81). It was estimated that 3.5% fuel savings is achieved by lead-free vehicles with catalytic converters vs their leaded "twins".

Analysis carried out by Davis Engineering Limited supports the proposition that fuel economy benefits are to be realized by lead-free-fuelled vehicles in the higher inertia weight categories of vehicles (82). A later report reiterated that vehicles using lead-free gasoline generally have a lower

fuel consumption rating than leaded gasoline vehicles and that, again, this is more apparent for heavier vehicles (83). Whereas the Davis study concludes that a potential savings (lead-free vs leaded) of 3.0% of total gasoline usage could have been realized if all manufacturers had changed over to lead-free vehicles in 1975, it is also stated that potential fuel savings decreased from 1975 to 1981 due to the trend to convert from leaded to lead-free vehicles. The further conclusion is that potential savings are levelling off, indicating that minimum savings may be expected in future years.

In the Control Options Report (2), Environment Canada estimated fuel consumption savings of 4% of forecast leaded gasoline sales if, in 1986, all leaded vehicles were replaced by lead-free vehicles. The basis of this estimate was an analysis conducted internally by the Mobile Sources Division of the Air Pollution Control Directorate which compared Canadian leaded with U.S. lead-free "twins" using published fuel ratings (84). Initially, it was estimated that a difference of 2.8% fuel consumption exists in favour of the U.S. lead-free vehicles.

It was further assumed by Environment Canada that future leaded car models, notably GM's Chevette, will have fuel penalties in excess of 10%. Based on this prognosis, the overall leaded fleet fuel penalty of 2.8% was escalated to 4.0%.

Industry Criticism of Studies

The numerous submissions made by industry and other parties criticized the underlying assumptions and/or data used in the above studies and, therefore, the estimated fuel savings. In addition to the obvious problem of using historical data, as in the case of the HPI and Davis studies, other comments (56) relate to limitations in the methodology which the originators of the studies doubtlessly recognize and acknowledge, namely the size of data base, the error factor of laboratory fuel ratings, the difficulty of selecting "twin" leaded and unleaded vehicles for comparison, etc. ILZRO's comment (56) that Environment Canada's 2.8% fuel economy savings overstates the effect of one model is perhaps valid; an investigation of the data in question reveals that this 2.8% is comprised largely of only a few paired comparisons within the total available leaded models and, in certain instances, that the basis of this comparison (engine size and design), while perhaps unavoidable in terms of selecting identical twins, is in truth questionable (85). The error of the 4.0% fuel economy penalty used is compounded by inflating the 2.8% penalty to reflect an anticipated but unsubstantiated future penalty of a leaded vehicle which is not yet on the market.

Conclusion

It may be concluded from the findings that there are fuel savings to be realized when current leaded automobiles are converted to lead-free use and are catalyst-equipped. Furthermore, this appears to be true of the larger inertia weight and engine-sized automobiles.

As to the amount of fuel savings, it is obvious that no consensus exists. Furthermore, whether for reasons of historical data, limited data

base, or non-comparable "twins", there is sufficient doubt to preclude any such selection being made with confidence.

Faced with this problem and accepting as given that some degree of fuel economy savings may be realized through the conversion of leaded vehicles to lead-free usage, the only recourse is to select and use a range of fuel savings which, at the upper limit, does not overly exceed reasonable expectations.

Inasmuch as the Davis estimate of 3.0% was based on 1975-1981 data and the consultants themselves concluded that the potential for savings would be less in future years, the estimate is excluded. The HPI estimate of 3.5% referred to leaded vehicles becoming lead-free and catalyst-equipped and does not equate to a 3.5% savings on the total existing leaded gasoline fleet. This savings would therefore be reduced, presumably, to the extent that leaded vehicles are converted to lead-free usage, but without a catalytic converter.

In the absence of confidence in the numbers provided in support documents, it is not the role of this study to select a purely arbitrary upper limit of fuel savings. Even though the 2.8% estimate calculated by Environment Canada is not without probable error, it is the lesser of the estimates available and is thus used as the upper limit of fuel savings on leaded gasoline volume.

Overall Gasoline Fleet Fuel Consumption

When calculating the amount of fuel savings to be realized, it was necessary to make assumptions regarding both the average annual distance travelled and the fuel consumption rating of these vehicles, 1987 and beyond. As described elsewhere, an average annual distance travelled of 16,000 km/year is used (42). Also, the Company Average Fuel Consumption (CAFC) objective for 1985 of 8.6 litres/100 km (33 miles/imp. gal) applicable to Canadian automobile manufacturers is assumed (58). This is a voluntary objective at the moment, backed by legislation which has been passed but not enacted.^a In the absence of any other firm data, it is judged practical to use this rating as representative of vehicles in 1987 and beyond.

Dollar Value of Fuel Savings

The Control Options Report used values for the price per litre of gasoline which were projected to increase in real terms. At the time the analysis was conducted, this appeared reasonable. Whereas other costs were projected to increase in proportion to each other and were therefore held constant in 1982 dollars, the National Energy Program outlook was projecting substantial increases in the cost of crude and, therefore, real increases in fuel prices.

Now, however, it would appear more reasonable to assume that the price of gasoline will not increase in real terms over the time horizon used in

^a In the U.S., the Corporate Average Fuel Economy (CAFE) objective of 27.5 miles/U.S. gal. is regulated (converts to 8.6 litres/100 km).

the study. This is based on the fact that world crude oil prices are softening and are projected to be substantially less than the NEP outlook. Even if Canada were to go to free market pricing in 1985, there would probably be a slight increase in crude costs, but moderate increases thereafter more in keeping with nominal price increases of other goods (44).

There are alternative ways of valuing the fuel saved as a result of conversion from leaded to lead-free gasoline. One method would be the resource cost of a litre of gasoline made from imported crude oil (this would measure the opportunity cost of gasoline that would otherwise have had to be made using imported crude under the assumption that, at the margin, additional supplies of crude would have had to be imported to meet domestic demand. The price per litre saved would thus be measured by the world price of crude, plus value-added in processing (not including government taxes, which are a transfer payment from the refiner to the government, not a real resource cost).

An alternative method of valuing the fuel savings would be to use retail pump prices (i.e., producers' price plus taxes less government subsidies) on the assumption that the value of each litre of gasoline saved is the price that consumers would otherwise have been willing to pay for it. This "willingness-to-pay" approach is the method used to value gasoline savings here. Its use is consistent with Treasury Board's "Benefit-Cost Analysis Guide" which states, in part,

"in calculating the benefit of public projects, the proper valuation to use is the price consumers are willing to pay for the output, that is, producers price plus taxes minus subsidies" (86).

The pump price of 46¢/litre is a composite of data received from Statistics Canada (87) and EMR (88). Table D-12 gives details of the foregoing calculations.

MAINTENANCE SAVINGS WITH LEAD-FREE GASOLINE

A study conducted by Hickling Partners Inc. concluded that reduced vehicle maintenance costs would result from the elimination of lead in gasoline (42). One of the side-effects of lead as a gasoline additive is to foul fuel-related components as a result of the deposition of lead salts. These same salt deposits corrode the exhaust system.

The use of lead-free gasoline was found to: decrease spark plug replacement by 25% to 49%; decrease exhaust system (muffler) failure by 42% to 96%; and not significantly affect any other vehicle system or parts. The average service benefits were estimated to be a 40% decrease in spark plug replacement; and a 47% decrease in exhaust system replacement. These, in turn, were calculated as representing savings of \$1/1000 km over the average automobile life of 10 years and 160,000 kilometres.

Three assumptions have been included in the calculations:

- research indicated that no measureable change in servicing requirements would occur if even low levels of lead were present in gasoline. The calculation of savings, therefore, is premised solely on a lead-free option;

TABLE D-12 ESTIMATED FUEL SAVINGS - OPTIONS #4 & 5 (BASED ON NEW PASSENGER CAR SALES)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Accumulative Leaded Passenger Car Sales ^a (x 10 ⁶)	0.15	0.31	0.47	0.63	0.79	0.96	1.13	1.31	1.49	1.68	1.87	1.94	1.99	2.04	2.09	2.14	2.20	2.26	2.30	2.36
Kilometres Driven @ 16,000/yr (x 10 ⁹)	2.40	4.96	7.52	10.08	12.64	15.36	18.08	20.96	23.84	26.88	29.92	31.04	31.84	32.64	33.44	34.24	35.20	36.16	36.80	37.76
Litres @ 11.7 km/L (CAFC Voluntary Objective) (x 10 ⁶)	205	424	643	862	1080	1313	1545	1791	2038	2297	2557	2653	2721	2790	2858	2926	3009	3090	3145	3227
Fuel Economy (x 10 ⁶)																				
- 4%	8.2	17.0	25.7	34.5	43.2	52.5	61.8	71.6	81.5	91.9	102.3	106.1	108.8	111.6	114.3	117.0	120.4	123.6	125.8	129.1
- 2.8%	5.7	11.9	18.0	24.1	30.2	36.8	43.3	50.1	57.1	64.3	71.6	74.3	76.2	78.1	80.0	81.9	84.3	86.5	88.1	90.4
Savings (x 10 ⁶)																				
- 4% @ 46¢/L	3.8	7.8	11.8	15.9	19.9	24.2	28.4	32.9	37.5	42.3	47.1	48.8	50.0	51.3	52.6	53.8	55.4	56.9	57.9	59.4
PV (\$1983) \$182b																				
- 2.8% @ 46¢/L	2.6	5.5	8.3	11.1	13.9	16.9	19.9	23.0	26.3	29.6	32.9	34.2	35.1	35.9	36.8	37.7	38.8	39.8	40.5	41.6
PV (\$1983) \$127b																				

^a Assume penetration complete by 1997.

^b 10% discount factor.

- in theory, servicing requirements could be reduced for existing leaded vehicles when switching to lead-free gasoline, in addition to the incremental savings realized by new vehicle sales (previously leaded-fuel designated but now, under the lead-free option, lead-free burning). Whereas conceptually this may be true, it would, however, be extremely difficult to estimate the age of these vehicles and their state of repair (e.g., condition of muffler) and the effect this would have upon average vehicle and total existing fleet maintenance costs. To account for all theoretical savings from the existing leaded fleet would undoubtedly be overstating the impact;
- therefore, even though savings could theoretically be realized by owners of existing leaded vehicles, the savings used for purposes of this study are those based solely on new vehicle sales, 1987 and beyond;
- all vehicles - passenger cars, light-duty trucks and medium/heavy-duty trucks - have been included in the calculations. Each category has the potential for savings from longer spark plug and muffler life.

Industry criticism centers on considerations of consumer behaviour, and the proposition that car owners do not necessarily follow manufacturers' maintenance instructions, e.g. changing spark plugs annually as part of regular, seasonal tune-ups. This, however, does not preclude savings from longer muffler life.

As for other aspects of consumer behaviour, these could perhaps be rectified by increased communication and awareness. This would not necessarily completely eradicate unnecessary seasonal spark plug replacement. However, the decision to eliminate savings based on existing leaded vehicles no doubt compensates for whatever error factor may be introduced by theoretical vs realistic consumer behaviour and maintenance savings on new vehicles. Calculations of maintenance savings are shown in Table D-13.

TABLE D-13 ESTIMATED MAINTENANCE SAVINGS - OPTIONS #4 & 5 (Based on New Vehicle Sales)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Leaded Gasoline Vehicles Sales (x 10 ⁶)	0.32	0.32	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.40	0.41	0.42	0.44	0.45	0.46	0.47	0.48	0.49
Accumulative Leaded Vehicles (x 10 ⁶)	0.32	0.64	0.97	1.30	1.64	1.99	2.35	2.72	31.0	3.49	3.88	4.04	4.14	4.24	4.36	4.46	4.58	4.70	4.80	4.92
km Driven @ 16,000/yr (x 10 ⁶)	5.12	10.24	15.52	20.8	26.24	31.84	37.6	43.52	49.6	55.84	62.08	64.64	66.24	67.84	69.76	71.36	73.28	75.2	76.8	78.72
Savings @ \$11,000/km (x 10 ⁶)	5.12	10.24	15.52	20.8	26.24	31.84	37.6	43.52	49.6	55.84	62.08	64.64	66.24	67.84	69.76	71.36	73.28	75.2	76.8	78.72
PV in \$1983 (\$ x 10 ⁶)	3.50	6.36	8.76	10.67	12.24	13.50	14.50	15.25	15.80	16.17	16.35	15.48	14.42	13.42	12.55	11.67	10.89	10.16	9.43	8.79
PV 239.91																				
*IF ONLY PASSENGER VEHICLES AND LIGHT TRUCKS	4.40	8.81	13.35	17.89	22.57	27.38	32.34	37.43	42.66	48.02	53.39	55.59	59.97	58.34	59.99	61.37	63.02	64.67	66.05	67.70
PV in \$1983 (\$ x 10 ⁶)	3.0	5.47	7.54	9.18	10.53	11.61	12.47	13.12	13.59	13.91	14.06	13.31	13.05	11.54	10.79	10.03	9.37	8.74	8.11	7.56
PV 206.98																				

a 14% of leaded vehicles account for medium/heavy vehicles

REFERENCES

1. Energy, Mines and Resources, "Implications of Reduced Lead-in-gasoline Limits for the Canadian Lead Industry", (June 9, 1982).
2. Environmental Protection Service, "Control Options for Lead Phase-down in Motor Gasoline", Environment Canada, (February 1983).
3. Econosult Inc., "Leaded Gasoline Excise Tax", Draft Final Report, (December 1982).
4. Royal Commission on Environmental Pollution, "Lead in the Environment", Ninth Report, HMSO, London, (April 1983).
5. Thatcher, R.W., Lester, M.L., McAlaster, R., and Horst, R., Arch. Environ. Health, 37: 159-161, (1982).
6. Neddleman, H., Glenoe, C., Leviton, A., Reed, R., Perasie, H., Mahr, C., and Barret, P., New England. J. Med., 300: 689-195, (1979).
7. Lansdown, R., Yule, W., Urbanowicz, M.A., and Millar, I.B., Lead Versus Health, John Wiley and Sons, New York, p. 267, (1983).
8. Givoni, S., Memo, M., Spano, P.F., and Trabucci, M., Toxicology, 12: 3-343-349, (1979).
9. Piomelli, S., Seman, C., Zullo, D., Curran, A., and Davidow, B., Proc. Nat. Acad. Sci. (USA), 79: 3335-3339, (1982).
10. Silbergeld, E.K., Lead Versus Health, John Wiley and Sons, New York, p. 191, (1983).
11. Concord Scientific Corporation, "Determination of Concentrations of Selected Fine Particulate Air Contaminants in Seven Canada Cities", report to the Environmental Protection Service, Dept. of the Environment, Contract No. OSS 80-00099, (March 1981).
12. Finlay, W.J., "Particulate Lead Concentrations at Curbside Sampling Sites in Canadian Urban Areas", Pollution Measurement Division, Environmental Protection Service, Dept. of the Environment, (June 1983).
13. Shelton, J., Personal Communication, NAPS Data Publications Unit, Dept. of the Environment, (August 1983).
14. Méraner, J.C., Subramanian, K.S., and Chalifoux, C., "Survey for Cadmium, Cobalt, Chromium, Copper, Nickel, Lead, Zinc, Calcium, and Magnesium in Canadian Drinking Water Supplies", J. Assoc. Off. Anal. Chem., 64: 44, (1981).
15. Méraner, J.C., Subramanian, K.S., and Chalifoux, C., "A National Survey for Cadmium, Chromium, Copper, Lead, Zinc, Calcium, and Magnesium in Canadian Drinking Water Supplies", Environ. Sci. Technol., 13: 707, (1979).

16. Nriagu, J.O., "Lead in Soil, Sediments and Major Rock Types", IN The Biogeochemistry of Lead in the Environment, Part A, Edited by J.O. Nriagu, Elsevier/North Holland Biomedical Press, Amsterdam, p. 15, (1978).
17. Wotton, D.L., and Doern, F.E., "Lead Particulate Analyses in Air and Soil in the City of Winnipeg 1982", Manitoba Environmental Management Division, Terrestrial Standards and Studies, Report 83-3, (April 1983).
18. Roberts, T.M., Hutchinson, T.C., Paciga, J., Chattopadhyay, A., Jervis, R.E., VanLoon, J., and Parkinson, D.K., "Lead Contamination Around Secondary Smelters: Estimation of Dispersal and Accumulation by Humans", Science, 186: 1120, (1974).
19. National Academy of Sciences, "Lead in the Human Environment", Washington, D.C., (1980).
20. Expert Advisory Committee, "Assessment of the Safety of Lead and Lead Salts in Food", Nutrition Foundation Inc., New York, (June 1982).
21. Chamberlain, A.C., "Fallout of Lead and Uptake by Crops", Atmos. Environ., 17: 693, (1983).
22. Huston, B.L., Health and Welfare Canada, Personal Communication, (August 1983).
23. Wigle, D.T., Charlebois, E.J., Eade, N.R., and Mehkeri, K.A., "Pediatric Blood Lead Screening in Montreal", Presented at Canadian Public Health Assoc. Annual Meeting, Edmonton, (1975).
24. Epidemiology Service, Dept. of National Health and Welfare, Ottawa.
25. Wigle, D.T., and Charlebois, E.J., "Electric Kettles as a Source of Human Lead Exposure", Arch. Environ. Health, (March/April): 72, (1978).
26. Neri, L.C., Johansen, H.L., Schmitt, N., Pagan, R.T., and Hewitt, D., "Blood Lead Levels in Children in Two British Columbia Communities", Trace Subst. Environ. Health, XII: 403, (1978).
27. Subramanian, K.S., and Meranger, J.C., "Blood Lead Levels of Cadmium, Copper, Lead and Zinc in a British Columbia Community", Sci. Total Environ., (In press, 1983).
28. Department of Public Health, City of Toronto, "South Riverdale Community Blood Lead Screening 1982", (March 1983).
29. Stiasny, S. "A Study of Area-specific Blood Lead Levels in Toronto Grade One Children", Report to Easter Health Area, Dept. of Public Health, City of Toronto, (March 1983).
30. Statistics Canada, Health and Welfare Canada, "The Health of Canadians - Report of the Canada Health Survey", Supply and Services Canada, Cat. No. 82-538E, Ottawa, (1981).

31. Hickman, J.R., McBain, D.C., and Armstrong, V.C., "The Contribution of Drinking Water to Exposure to Toxic Substances in Canada", Environ. Monit. Assess., 2: 71, (1982).
32. 1981 Census of Canada, "Population, Age, Sex and Marital Status", Catalogue No. 92-901, Volume 1 - National Series, Statistics Canada, p. 6.1., (September 1982).
33. Hammond, P.B., O'Flaherty, E.J., and Gartside, P.S., "The Impact of Air-lead on Blood-lead in Man - A Critique of the Recent Literature", Food Cosmet. Toxicol., 19: 631, (1981).
34. Chamberlain, A.C., "Effect of Airborne Lead on Blood Lead", Atmos. Environ., 17: 677, (1983).
35. Sherlock, J., Smart, G., Forbes, G.I., Moore, M.R., Patterson, W.J., Richards, W.N., and Wilson, T.S., "Assessment of Lead Intakes and Dose-response for a population in Ayr Exposed to a Plumbosolvent Water Supply", Human Toxicol., 1: 115, (1982).
36. Drill, S., Konz, J., Mahar, H., and Morse, M., "The Environmental Lead Problem: An Assessment of Lead in Drinking Water from a Multi-Media Perspective, U.S. Environmental Protection Agency, Report No. EPA 570/9-79-003, (May 1979).
37. Environmental Health Directorate, "Tapwater Consumption in Canada", Publ. by Health and Welfare Canada, (November 1981).
38. Shaper, A.G., Pocock, S.J., Walker, M., Wale, C.J., Clayton, B., Delves, H.T., and Hinks, L., "Effects of Alcohol and Smoking on Blood Lead in Middle-aged British Men", Brit. Med. J., 284: 299, (1982).
39. Commission of the European Communities, "Isotopic Lead Experiment", Status Report, Report No. EUR 8352 EN, (July 1982).
40. Annett, J.L., Pirkle, J.L., Makuc, D., Neese, J.W., Bayse, D.D., and Kovar, M.G., "Chronological Trend in Blood Levels Between 1976 and 1980", N. Engl. J. Med., 308: 1373, (1983).
41. a) Rabinowitz, M.B., and Needleman, H.L., "Temporal Trends in the Lead Concentrations of Umbilical Cord Blood", Science, 216: 1429, (1982);
b) Rabinowitz, M.B., and Needleman, H.L., "Petrol Lead Sales and Umbilical Cord Blood Levels in Boston, Massachusetts", The Lancet, (i): 63, (1983).
42. Hickling-Partners Inc., "Assessment of the Economic Impact on the Automotive Parts/Service Industry of Proposed Lead Content Regulations", (March 31, 1981).
43. MHG International Ltd., "Study on the Incremental Refinery Construction Costs Associated with the Reduction in the Amount of Lead Additive in Gasoline", (December 1981).
44. Monteiro, N.X., National Energy Board, Personal Communication, (August 25, 1983).

45. National Energy Board, "1982 Omnibus Gas Export Hearing Forecast", (December 1982).
46. Taylor, G., Energy, Mines and Resources, Transportation Energy Division, letter to M.E. Rivers, Environment Canada, (August 23, 1983).
47. Air Pollution Control Directorate, "Yearly Report of Lead Additives Usage in Refineries (and Imported Gasoline)", Environment Canada, (1982).
48. MHG International Ltd., "Incremental Costs to the Refining Industry Associated with the Removal of Lead Antiknock Additive in Gasoline Based on Product Specifications Issued by the Canadian Government Specifications Board", (August 1981).
49. Rinaldi, J., Transport Canada, letter to J. Labuda, Environment Canada, (February 16, 1983).
50. Hogg, W.J., PACE, letter to M.E. Rivers, Environment Canada, (November 20, 1981).
51. PACE, "Comments on the Proposed Phase-down of Lead in Motor Gasoline", submitted to Environment Canada, (May 1983).
52. Environment Canada, discussions during project analyses with J. Labuda and F. Landheer, (September 1983).
53. MGH International Ltd., "A study on the Incremental Capital and Operating Costs to the Lead Antiknock Manufacturers Associated with the Reduction in Lead Antiknock Usage in Gasoline", (May 1981).
54. Pilorusso Research Associates Ltd., "An Analysis of the Estimated Costs and Benefits of Lead Traps Relative to Conventional Muffler Systems", (November 1982).
55. E.I. Du Pont de Nemours & Company, "Recycle of Vehicle Exhaust Lead Traps", (July 30, 1976).
56. International Lead Zinc Research Organization, Comments on "Control Options for Lead Phase-down in Motor Gasoline" by Environment Canada, Canadian Energy and Emissions Committee, (May 1983).
57. Du Pont Canada Inc., "Estimated Motor Gasoline Consumption Forecast (ESCON) 1968-1990", (May 1983).
58. Hrobelski, L., Transport Canada, Personal Communication, (August 1983).
59. National Energy Board, "Canadian Energy Supply and Demand, 1980-2000", (June 1981).
60. Energy, Mines and Resources, ISFD Model.
61. Waghmare, R., National Energy Board, Personal Communication, (August 1983).

62. Ethyl Corporation, "Gasoline Sales for First 5 Months, 1983", Oilweek, (August 1983).
63. Du Pont Canada Inc., "Forecast of Gasoline Demand through 1990", (October 1981).
64. Ethyl Corporation of Canada Ltd., "Gasoline Demand Forecast", from internal analysis by Environmental Protection Service, (January 1983).
65. Du Pont Canada Inc., "Estimated Motor Gasoline Consumption Forecast (ESCON) 1968-1990", (October 1982).
66. Henderson, D., Du Pont Canada Inc., Personal Communication, (August 1983).
67. Lyall, R., Du Pont Canada Inc., letter to J. McMullen, James F. Hickling Management Consultants Ltd., (August 3, 1983).
68. Labuda, J., Environment Canada, Personal Communication, (September 1983).
69. Gullon, A., Mobile Source Division, Environment Canada, Internal Communication.
70. Giles, P., Environment Canada, Personal Communication, (August 1983).
71. Treasury Board Canada, "Administrative Policy Manual", Chapter 490, "Socio-economic Impact Analysis", (December 1979).
72. Ethyl Canada Inc., "Impact of Lead Antiknock Removal on Refinery Energy Consumption", (January 1982).
73. MHG International Ltd., "Assessment of Three Scenarios for Gasoline Production in Canadian Regions", (December 1981).
74. MHG International Ltd., "Incremental Costs to the Refining Industry Associated with the Reduction in Lead Antiknock Usage in Gasoline", (December 1981).
75. Labuda, J., Environment Canada, Internal Communications with F. Landheer, (August, September 1983).
76. U.S. EPA, "The Impact of Lead Additive Regulations on the Petroleum Refinery Industry: Vol. 1 - Project Summary", (May 1976).
77. CAA, Submission to Minister of Environment, (May 10, 1983).
78. O' Riordan, F., Treasury Board Canada, Internal Communication, (August 1983).
79. Green, W., General Motors of Canada, Personal Communication, (August 1983.)
80. Hickling-Partners Inc., "Investigation of the Effect of Fuel Type and Compression Ratio on Fuel Consumption", (March 1981).

81. Hickling-Partners Inc., "Automotive Fuel Consumption Analysis - U.S. vs Canada" (1983).
82. Davis Engineering Limited, "Comparison of Fuel Consumption between Vehicles Equipped to Use Leaded and Unleaded Fuels", (March 1981).
83. Davis Engineering Limited, "Gasoline Fuel Savings in Canada as a Result of Using Lead-free Gasoline in Cars", (October 1981).
84. Environment Canada, "Comparison of Fuel Consumption of Canadian-specific Lead-tolerant Vehicles with Identical U.S. Unleaded-fueled Vehicles for the 1982 Model Year", Mobile Sources Division, (December 1982).
85. Environment Canada, Mobile Sources Division, Personal Communication with D. Gourley, (August 1983).
86. Treasury Board Canada, "Benefit-Cost Analysis Guide", Planning Branch, (March 1976).
87. Bonhomme, M., Statistics Canada, Personal Communication, (August 1983).
88. Young, D., Energy, Mines and Resources, Petroleum Product Marketing, Personal Communication, (August 1983).

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